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DOUGLAS-FIR MANAGED YIELD SIMULATOR --

DFIT USER'S GUIDE

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Abstract

DFIT simulates the yields of managed Douglas-fir stands. Management practices that can be simulated include planting, precommercial thinning, commercial thinning, and fertilization. Equations used in DFIT describe growth of natural stands, estimate the volume increment of thinned stands and plantations, and predict amount and timing of mortality. Changes in most of these estimates can be made by the user without destroying consistency of other estimates.

KEYWORDS: Computer programs, thinning (tree), increment estimates (stand), yield (forest), growing stock (-increment/ yield.

Metric Equivalents

1 inch = 2.540 centimeters
1 foot = 0.3048 meter
1 square foot = 0.09290 square meter
1 cubic foot = 0.02832 cubic meter
1 square foot per acre = 0.2296 square meter per hectare
1 cubic foot per acre = 0.06997 cubic meter per hectare

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Introduction

Estimates of yields of managed Douglas-fir stands were prepared in 1972.[1] Management practices included commercial thinnings, precommercial thinning, and fertilization. These estimates have since been used for several purposes both in and outside the Forest Service. Most users requested more details concerning the stands than those supplied by the original estimates. These requests led to the development of a method of simulating stand growth and a computer program DFIT (Douglas-fir Interim Tables) to tabulate the results of the simulation.

The basic components of DFIT are: (1) equations describing the development of natural stands, (2) thinning guides[2] based on Reineke's stand density index,[3] (3) equations describing the total cubic-foot increment of thinned stands and plantations, (4) equations predicting amount and timing of mortality in natural stands, (5) a method for describing stand components at intervals without the direct use of stand and stock tables, and (6) many assumptions about management practices and their effects on stand development. These assumptions are based on careful study of currently available results of Douglas-fir thinning studies. They have been balanced against growth of natural stands and have been checked for internal compatibility and consistency.[4]

Since no stands in the Pacific Northwest have been thinned regularly for 60 to 80 years, the yields estimated by the simulator are extrapolated far beyond the available data base. The extrapolations seem reasonable to the authors and several users, but this is no demonstration of their validity. The growth rates and other factors affecting yield will need revision when results of a current cooperative study of managed Douglas-fir yields are published. The program is written so that changes in most estimates can be made without destroying the consistency of other estimates. Estimates are for net forest acres and gross volume yields. Appropriate deductions should be made for roads and other nonforested areas and for breakage during harvesting.

DFIT was made as flexible as possible, but it was necessary to control some relations by rather rigid assumptions. Within limits DFIT allows the user much more freedom to test and observe probable results of different management regimes than do many other stand growth simulators.

This paper explains how to use the simulator and describes its operation in enough detail that the reader can make his own adjustments. The paper starts with a description of program output and several examples followed by a description of how to control the program and some of the limits that should be observed. The function list displays operating assumptions and suggests how some may be modified to test other assumptions. Finally, there is a brief discussion of how to change some functions. Symbols and abbreviations are defined in the appendix. Arrangements for obtaining program decks can be made with Project 1301 or Project 1207, Pacific Northwest Forest and Range Experiment Station. For Forest Service users, DFIT is available on the UNIVAC at Fort Collins, Colorado.

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[1] Bruce, David, and D. L. Reukema. Douglas-fir managed yield tables. Unpublished 1972 report on file at Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

[2] Reukema, Donald L. 1975. Guidelines for precommercial thinning of Douglas-fir. USDA For. Serv. Gen. Tech. Rep. PNW-30, 10 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

[3] Reineke, L. H. 1933. Perfecting a stand-density index for even-aged forests. J. Agric. Res. 46(7):627-638, illus.

[4] Reukema, Donald L., and David Bruce. 1977. Effects of thinning on yield of Douglas-fir: Concepts and some estimates obtained by simulation. USDA For. Serv. Gen. Tech. Rep. PNW-58. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Yield Tables

EXPLANATION OF DFIT OUTPUT

Each table produced by DFIT starts with a list of the variables specified by the user and some of the assumptions included in the run. The list length varies with the number of optional controls used.

The first example illustrates some simple assumptions (table 1, fold out front cover so table can be followed as text is read; other tables are in the appendix). In this example, a fully stocked natural stand of Douglas-fir on site 140 is to be commercially thinned when its merchantable trees average 8 inches in diameter. In such a natural stand, trees larger than 6 inches are considered merchantable. This commercial thinning will be followed by a thinning 10 years later and a harvest cut at age 60. A financial summary is included, discounting stumpage values at 6 percent to date of first commercial thinning. Harvest stumpage is $150 per thousand board feet, Scribner scale, and thinning stumpage $120. A summary table and a comparison with a natural unthinned stand are requested. There is no implication that this is a recommended or optimal schedule--it was chosen to illustrate the main features of the output in as small a space as possible. The information at the head of table 1 lists the assumptions: the site index (100-year basis), the average diameter of the merchantable part of the stand at first possible commercial thinning (CT), the minimum diameter limit for merchantable trees, whether the stand was precommercially thinned, the thinning interval (10 years), thinnings (two), the harvest age (60 years), and the financial details.

Throughout the table average numbers are stated with sufficient digits to allow checks of consistency. The extra digits do not imply accuracy and should be dropped when comparisons with other schedules are made. Total age is given in years for each date of thinning or harvest. Average height of dominants and codominants is stated in feet. Mean d.b.h. for tree of average basal area is given in inches. Mean G is the basal area of the average tree in square feet. Volume of the tree of mean basal area is in cubic feet and includes tip and stump. The volume-basal area ratio has a dimension of feet.

Volumes per acre are given in table 1 as total cubic feet including tip and stump (CVT), cubic-foot volume above a stump that is 1 percent of total height to a 4-inch d.i.b. limit (CV4), International 1/4-inch rule to a 5-inch d.i.b. limit (IV5), and Scribner formula to a 6-inch top (SV6). Both board-foot estimates are based on 16-foot logs scaled to the nearest one-tenth inch. It is not possible to accurately estimate Scribner board feet for small trees when 32- or 40-foot logs are scaled to the next lower inch. A crude approximation can be obtained by multiplying stated Scribner by 80 percent.

In table 1 the number of trees per acre is stated. "G per acre" is basal area per acre in square feet. Current price is listed to the nearest dollar based on the given stumpage and the estimated Scribner volume thinned or available for harvest at the given age. Discounted price is the current price discounted to date of first commercial thinning. Cumulated price is the sum of all previous thinning values and the harvest value of the current merchantable stand discounted to date of first commercial thinning.

In the third column of the tables the labels identify the stand component described in each line. The label "first poss" is followed by a description of the stand at the fractional year when it first reaches the specified minimum diameter for CT. The stand completes its growth for that year before it is broken down into the components that can be recognized at the time of the first CT.

The label "total before" precedes a description of the stand component that includes trees below the merchantable d.b.h. limit which are identified as "submerch." It is assumed that practically all of these trees will die before reaching merchantable size. Table 1 also includes a "merchantable" label which is followed by the description of the stand component that can be thinned or projected forward in time. "Cut" is the part of the merchantable stand removed in thinning. "Merch leave" is the part of the merchantable stand left after thinning. "Total leave" is the total living stand immediately after thinning.

The first summary line ("sum gross") shows gross volume per acre, the sum of the volume of living trees at a given date plus the volume of all trees previously cut or dead. The sum of the merchantable volume ("sum merch") is the present merchantable volume plus all volume previously cut. The sum of the cut is the total cut up to and including the current thinning. The mean diameter of all cut trees to date is stated in this line, as is the number of cut trees. The summaries also show the basal area of trees whose volume is reported.

"Vol growth" is the estimated cubic-foot increment for the period between thinnings. It is one of the three elements that make it possible to simulate growth of the stand between dates of cutting. The other elements are changes in dominant and codominant height and number of trees. "Sub merch mortality" is the mortality occurring since the last thinning. The number of dead submerchantable trees starts the report on second cut and is used in the calculation of stand components for the current date. It is assumed that no merchantable trees die in the interval except those that can be salvaged with the current cut.

The subsequent lines for the stand at the time of the second cut at age 46 correspond to those for the stand at the time of the first cut. The program will report 19 dates of thinning.

For the final cut the table includes the first three lines of a thinning report and then repeats the "merchantable" part as the harvest. A final summary of gross, merchantable, and cut volumes completes the main report.

A summary table is printed after the main table, if requested. It repeats the per-acre data for the total and merchantable live stand before each cut (table 1A).

If requested, a report (table 1A) is printed showing development of natural stands growing on the same site and at the ages of the preceding table. Most of the column headings and line captions for table 1A are the same as in table 1. No data are reported until the natural stand reaches the specified merchantable size. Stumpage values are discounted to age of first commercial thinning in the previously described managed stand. This part of table 1A is much the same as a table that could be derived from Technical Bulletin 201[5] except that it describes the mortality occurring between two ages. These dying trees (table 1A) are assigned sizes and are separated into submerchantable mortality and merchantable mortality.

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[5] McArdle, Richard E., Walter H. Meyer, and Donald Bruce. 1949. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agric. Tech. Bull. 201 (rev.), 74 p., illus.

EFFECT OF VARYING ASSUMPTIONS

Changing controls will change the estimates. If the average size of the merchantable stand is increased from 8 to 10 inches, the minimum merchantable diameter at each cut and the age at first possible thinning are increased. These changes affect most parts of the consequent estimates (table 2).

The date of the first commercial thinning (table 3) is deferred with controls changed back to an 8-inch average merchantable stand. This change increases tree size and yield at first commercial thinning but reduces yield at harvest date.

Assuming the stand was precommercially thinned (PCT) makes even greater changes in the estimates (table 4). In DFIT it is assumed that all trees left after PCT reach the specified minimum merchantable diameter. Any trees that might die later are included in the next thinning, so the table includes no accounting for mortality, shortening the table considerably. If they are requested, the summary table and the natural stand table contain the same information as in table 1A.

Another variation in assumptions is that the thinning cycle is controlled by the time the stand makes a specific amount of height growth (table 5). The program calculates the fractional year for completion of this growth and goes to the nearest full year.

The effect of fertilizing with 200 pounds of nitrogen per acre can be simulated. Either fertilizing at time of CT or at certain ages after first CT can be specified (table 6). PCT is assumed to improve the site, and growth resulting from fertilization will be calculated on the basis of this improved site.

Stands with PCT can also have delayed CT (table 7).

Plantation growth can be simulated by setting PCT age at 2 years (table 8). If this is done, the implicit assumption is that the stand does not suffer losses common in most Douglas-fir plantations. The example is listed for comparison with the next example, not as an illustration of average plantation yields.

A user option can increase growth for the life of the tree and simulate genetically superior trees grown in plantations (table 9). This is one example of four user supplied estimates of gains or losses in growth. This example assumes a change in growth that affects the entire life of the stand but not the corresponding natural stand. Other assumptions change growth from PCT to harvest and from first CT to harvest. A fourth assumption changes growth rate of natural stands as well as managed stands.

Control Cards

Usually a single control card will produce a table for one set of assumptions. Extra cards are used only when ages at time of thinning or fertilizing are specified.

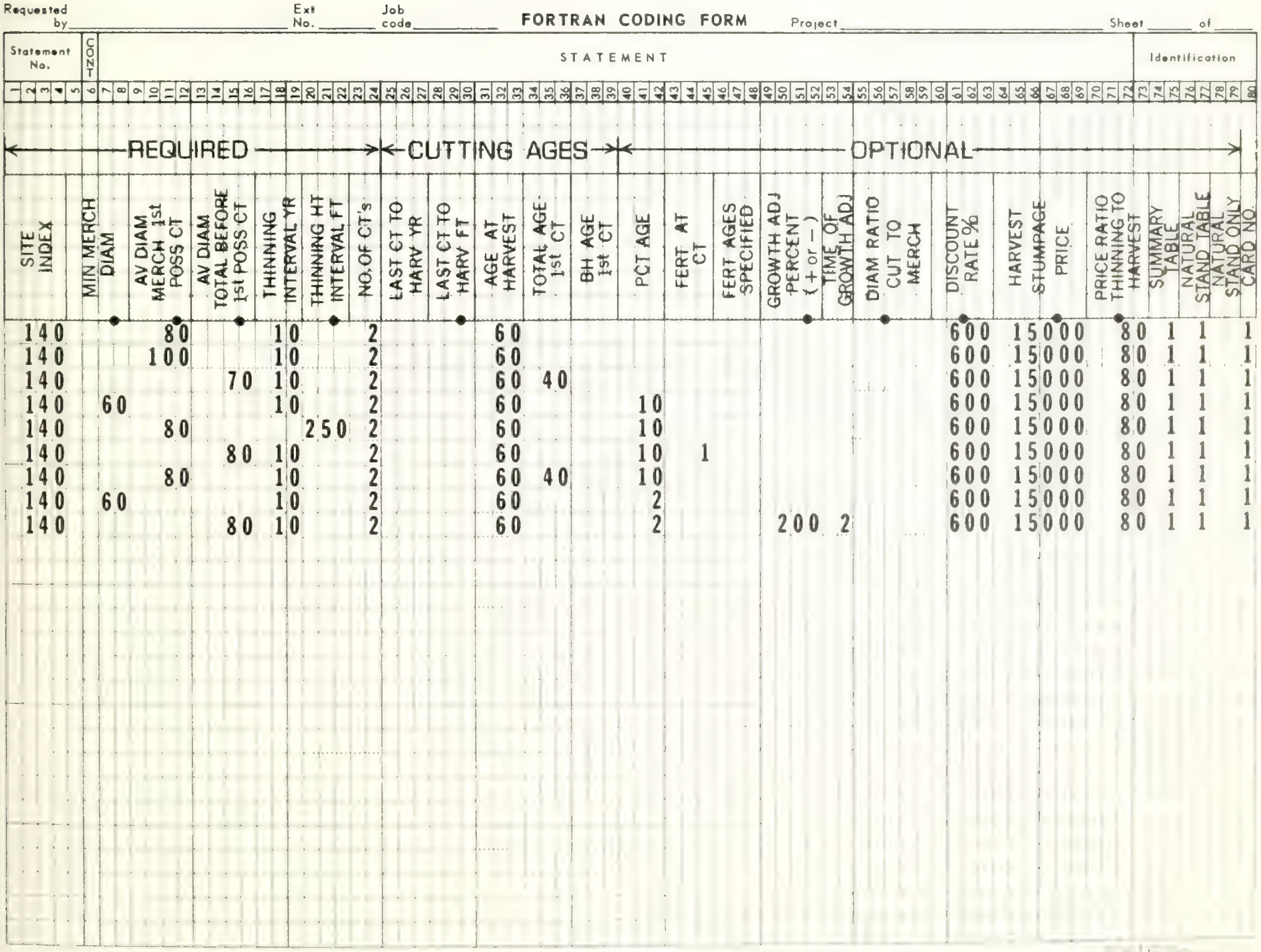
Required assumptions are: (1) site index (100-year basis), (2) a minimum merchantable diameter or a mean diameter for first possible CT, (3) interval between CT's, and (4) number of CT's.

A set of controls of cutting ages is included that makes possible complete specification of the schedule in several ways.

Optional assumptions are: (1) PCT, (2) fertilization, (3) user supplied percentage change in growth, (4) diameter ratio of cut component to merchantable stand, (5) financial report, (6) summary table, and (7) natural stand table.

The rules for setting up control cards follow. Dots on the line under the headings indicate location of implied decimals (fig. 1).

Figure 1.--Coding form, DFIT control card 1.



Requested by ______ Ext No. ______ Job code ______ **FORTRAN CODING FORM** Project ______ Sheet ______ of ______

REQUIRED							CUTTING AGES					OPTIONAL												
SITE INDEX	MIN MERCH DIAM	AV DIAM MERCH 1st POSS CT	AV DIAM TOTAL BEFORE 1st POSS CT	THINNING INTERVAL YR	THINNING HT INTERVAL FT	NO. OF CT's	LAST CT TO HARV YR	LAST CT TO HARV FT	AGE AT HARVEST	TOTAL AGE 1st CT	BH AGE 1st CT	PCT AGE	FERT AT CT	FERT AGES SPECIFIED	GROWTH ADJ PERCENT (+ or −)	TIME OF GROWTH ADJ	DIAM RATIO CUT TO MERCH	DISCOUNT RATE %	HARVEST STUMPAGE PRICE	PRICE RATIO THINNING TO HARVEST	SUMMARY TABLE	NATURAL STAND TABLE	NATURAL STAND ONLY	CARD NO.
140		80		10		2			60									600	15000	80	1	1		1
140		100		10		2			60									600	15000	80	1	1		1
140			70	10		2			60	40								600	15000	80	1	1		1
140	60			10		2			60			10						600	15000	80	1	1		1
140		80			250	2			60			10						600	15000	80	1	1		1
140			80	10		2			60			10	1					600	15000	80	1	1		1
140		80		10		2			60	40		10						600	15000	80	1	1		1
140	60			10		2			60			2						600	15000	80	1	1		1
140			80	10		2			60			2			200	2		600	15000	80	1	1		1

REQUIRED CONTROLS

Site index (100-year basis) is specified in feet (cols. 2-4).

A minimum merchantable diameter limit is stated (cols. 6-8) or is based on one of the following assumptions:

(a) Merchantable stand diameter at first possible CT (cols. 10-12): minimum merchantable diameter is 75 percent of merchantable stand diameter.

(b) Total stand diameter at first possible CT (cols. 14-16): minimum merchantable diameter is 87.5 percent of total stand diameter in natural stands, and 75 percent of total stand diameter in PCT stands.

If more than one diameter is stated, the program (1) uses the specified minimum merchantable diameter and calculates the other diameters or (2) uses the specified average merchantable diameter and calculates the specified average stand diameter.

Intervals between thinnings are specified either as years (cols. 18-19) or as a given amount of height growth (cols. 20-22). If some other schedule is wanted, these columns are left blank and the ages at time of thinning and final harvest are entered on control card 2.

The number of CT's should be specified (cols. 23-24) the first time DFIT is used. The report will start with the earliest possible CT for the given site and will list the CT's plus a final harvest after the last CT at the same interval as the thinning interval. Review of this report makes it possible to choose a thinning schedule that has a long enough interval to get desired minimum thinning volumes and has enough thinnings to keep the stand growing vigorously until some specified final harvest date. Generally this selected schedule will make the interval between final CT and final harvest greater than the interval between CT's.

CUTTING AGE CONTROLS

Interval from last CT to final harvest can be specified in years (cols. 26-27) or feet of height growth (cols. 28-30). If this interval is not otherwise specified, the simulator will use the thinning interval in years.

If specified, age at final harvest (cols. 31-33) will override the statement of number of CT's when there are more CT's than can be made between first CT and final harvest. The interval between the last CT and harvest will be set equal to or less than the thinning interval. If both harvest age and the thinning cycle are specified, the number of CT's does not have to be stated.

The first CT can be delayed by specification of total age (cols. 35-36) or breast-high age (cols. 38-39) at first CT. If, inadvertently, age specified is less than the age at which the stand reaches the given merchantable limit, the program prints a comment and a table, with the first CT done the year after the limit is reached.

After tables based on schedules developed by these controls have been examined, precise schedules based on use of control card 2 may seem desirable.

OTHER OPTIONAL CONTROLS

The next optional control is the age of PCT (cols. 41-42). The program was designed for ages between 10 and 20 years, and will not run for greater ages. Plantations can be simulated by setting the PCT age at 2 years. If this is done some adjustment of predicted growth should be considered to allow for failed spots, inappropriate genetic stock, and the vicissitudes of early plantation life. PCT in natural stands enables selection of vigorous trees that have been tested in situ.

The next option is fertilization. The gains built into the program are controlled by calling for either fertilized in year of CT (col. 45) or fertilized at ages specified (col. 48). These options are activated by putting "1" in the appropriate column. If fertilized at ages specified is called for, control card 3 must be prepared and put in the deck. The assumption is that fertilizer effects vary with site and last 10 years. See discussion of function 7-0, p.14. It is assumed that 200 pounds N per acre is applied and increases growth for 10 years. If the stand is fertilized at intervals of less than 10 years, the increase is doubled during the overlapping periods of effectiveness.

To change the growth assumptions in DFIT, a user's estimate of gain or decrease in growth (cols. 49-52) and time at which it starts (col. 54) can be entered. This option makes possible a change in growth rates for reasons such as genetic improvement, fertilization, or dissatisfaction with built-in growth estimates. A gain in growth is entered as a percent to the nearest tenth (cols. 49-52). A reduction in growth requires a minus sign (col. 49), followed by a percent.

Options for changing growth are: (1) To change growth of both natural and managed stands a "1" is entered in column 54 of control card 1. (2) If genetic gains are assumed, a "2" is entered in column 54 and a "2" in column 42. This assumes that genetically improved trees are planted. (3) If gains are assumed to start at date of PCT, a "3" is entered in column 54 and age at PCT in columns 41-42. (4) If gains are assumed to start at date of first CT, a "4" is entered in column 54. Each gain or loss affects growth from the selected starting time to the final harvest.

Since these gains or reductions are based on the volume growth function operating after first CT, they are only approximations for the preceding period (options 1, 2, or 3). The approximation can be improved by running the program twice and specifying a reasonable harvest age (cols. 31-33) with all controls the same except columns 49-54. The computed change in yield (CVT) can be compared with the user supplied estimate and the former adjusted to fine-tune the final estimate.

Diameter ratio of cut to merchantable stand before thinning (cols. 55-59) may be specified, to override the assumption built into the program that the first possible CT has a ratio of 1.0 and later CT's have lower ratios with a bottom limit of 0.8. A ratio thus specified will be used for all thinnings. An alternative adjustment is discussed under "Changing Functions."

The next three items give a means of looking at relative stumpage values. First a discount rate expressed in percent is selected (cols. 60-63). Then a stumpage price for final harvest cuts is specified (cols. 64-69), and last, the stumpage for thinnings is stated as a ratio of the harvest stumpage (cols. 70-73). All three items must be specified to get the financial report. (If stumpages are not stated, prices will be 0.)

A financial report is given for each age in the table. Cumulative price is the stumpage value of previously thinned stands plus standing timber discounted to age of first commercial thinning. In natural stands it is the stumpage value of standing timber discounted to same age.

The summary table is called by a "1" in column 75 and the natural stand table is called by a "1" in column 77. If only the natural stand table is wanted, a "1" is put in column 79. It is also necessary to specify ages to be reported, which is done by using any of the controls that call for reports on managed stands.

The control card number, which is 1, is specified in column 80.

When control card 2 is used (by leaving both thinning interval columns (18-19) and height interval columns (21-22) blank on control card 1), age at first CT is entered in columns 1-3. Successive CT ages are entered in columns 4-6, 7-9, ..., 58-60. This allows as many as 19 thinnings because the last age entered is assumed to be the time of final harvest. A "2" is punched in column 80 and the card is placed behind the appropriate control card 1.

When control card 3 is used (by punching "1" in col. 48 of control card 1), age at first fertilization is entered in columns 1-3. Successive fertilization ages are entered in columns 4-6, 7-9, 58-60. Since fertilization effects are assumed to last 10 years, it is unlikely that more than four or five ages will be specified. A "3" is punched in column 80 and the card is placed behind control card 1, or control cards 1 and 2.

Function List

The equations that control DFIT have been listed at the end of the program, making it easy to change assumptions. Some changes can be made with no concern for other equations, some imply changes in other equations, and others require changes to maintain consistency. Such dependencies will be noted in the ensuing discussion. The symbols used here and listed in the appendix are not the same as those in the program. Those used in the program must be used in changing the program. Many equations in this report state the dependent variable as $\log_{10} y$ (written as log y) to simplify typesetting. The functions in the program all state the dependent variable as y.

NATURAL STANDS

Calculate breast-high (b.h.) age of natural stand, given total age and site index:

$$A_B = A_T - 13.22 + 0.033S. \qquad (0\text{-}1)$$

If this equation is changed, equation 0-2 must be changed and equations 0-3 and 0-4 probably should be.

Calculate total age of natural stand, given b.h. age and site index:

$$A_T = A_B + 13.22 - 0.033S. \qquad (0\text{-}2)$$

If this equation is changed, equation 0-1 must be changed, and equations 0-3 and 0-4 probably should be. This equation implies a linear relation between site index and time from germination to breast height.

Calculate quadratic mean diameter of natural stand, given b.h. age and site index:

$$\log \bar{D}_G = 0.1097 - 3.4857/(A_B)^{0.25} + 1.0531 \log S. \qquad (0\text{-}3)$$

If this equation is changed, equation 0-4 must be and equations 0-5 and 0-6 probably should be. This equation and several others are based on reanalysis of the data on which USDA Technical Bulletin 201 (see footnote 5, p. 3) was based, plus some recently measured plots that furnish more information on young stands on poor sites. They give estimates for natural stands that are close to, but not identical with, those in Bulletin 201.

Calculate b.h. age of natural stand, given quadratic mean diameter and site index:

$$A_B = (3.4857/(0.1097 - \log \bar{D}_G + 1.0531 \log S))^4. \quad (0\text{-}4)$$

This equation is derived from equation 0-3, and 0-3 must be changed if 0-4 is. See the paragraph following equation 0-3 for other discussion.

Calculate trees per acre in natural stand, given b.h. age and site index:

$$\log N = 3.9108 + 5.2306/(A_B)^{0.25} - 1.5803 \log S. \quad (0\text{-}5)$$

This equation is derived from the same data as equation 0-3. Equations 0-3, 0-5, and 0-6 are a group that must be kept consistent.

Calculate basal area per acre in natural stand, given b.h. age and site:

$$\log G = 1.8669 - 1.7408/(A_B)^{0.25} + 0.5259 \log S. \quad (0\text{-}6)$$

This equation can be derived from equations 0-3 and 0-5 by:

$$\log G = \log N + 2 \log D + \log 0.005454154.$$

This relationship must be preserved if equation 0-3, 0-5, or 0-6 is changed.

Calculate average height of dominant and codominant trees in natural stand, given total age and site index:

$$\log \bar{H}_D = 0.1567 - 15.673/A_T + \log S. \quad (0\text{-}7)$$

This equation comes from the same data as equation 0-3 and gives close approximation of Bulletin 201 (see footnote 5, p. 3) site curves. It is independent of equations 0-3 through 0-6. If it is changed, equation 0-8 probably should be and equation 2-0 must be.

Calculate volume/basal area ratio of natural stand, given dominant and codominant height:

$$\log V/G = -0.0282 + 0.7917 \log \bar{H}_D. \quad (0\text{-}8)$$

This equation, derived from same data as equation 0-3, can be combined with equations 0-6 and 0-7 to get direct estimates of volume per acre in natural stands. It starts the volume estimate in the simulator.

Calculate volume per acre of natural stand, given site and age.

$$\log V = 1.9628 - 12.4083/A_T - 1.7408/(A_B)^{0.25} + 1.3176 S. \quad (0\text{-}9)$$

This equation, derived from 0-6, 0-7, and 0-8, is used only in equation 2-1. It does not appear alone in the function list of program DFIT.

STAND DENSITY RELATIONS

Calculate top limit of basal area in natural stand, given quadratic mean diameter:

$$\log G_L = 1.9882 + 0.4994 \log \bar{D}_G. \quad (1\text{-}0)$$

This equation is derived from Reineke's stand density index (see footnote 3, p. 1) which is based on $\log \bar{D}_G = f(\log N)$. Since $G = 0.005454\ \bar{D}_G^2 N$, the density index can be expressed by any of the six relations among pairs of the three variables. As used here, for a given $\bar{D}_G$, the limit of either G or N is 1.5 times the average density of all plots in the data set described under equation 0-3. Changes in this equation will affect operation of equation 2-3.

Calculate trees per acre in a PCT stand, given diameter at first possible CT:

$$\log N = 3.9591 - 1.5006 \log \bar{D}_F. \qquad (1\text{-}1)$$

This equation is derived from the same relation as equation 1-0. The stand density is about 76 percent of the average of all plots. If this equation is changed, equation 1-2 must be changed.

Calculate basal area per acre of merchantable trees, given average diameter of merchantable trees at first possible CT:

$$\log G_M = 1.6958 + 0.4994 \log \bar{D}_F. \qquad (1\text{-}2)$$

If this equation is changed, equation 1-1 must be.

Calculate recommended level of basal area after first CT, given average diameter of merchantable trees before thinning:

$$\log G_R = 1.3275 + 0.6917 \log \bar{D}_M. \qquad (1\text{-}3)$$

This equation is derived from same relation as equation 1-0. It gives a basal area of about 50 percent of average natural stand density when stand diameter is 8 inches and 80 percent when stand diameter is 30 inches. If this equation is changed, equation 1-4 must be.

Calculate average diameter of merchantable trees in stand, given recommended level of basal area after CT:

$$\log \bar{D}_M = -1.9192 + 1.4457 \log G_R. \qquad (1\text{-}4)$$

This equation is derived from equation 1-3. The two equations are used with a given d/D ratio to estimate diameter and basal area of merchantable trees after thinning. See also equations 6-0 and 6-1.

GROWTH FUNCTIONS

Calculate 1-year height growth of dominant and codominant trees, given total age and site index:

$$\log d\bar{H}_D/dA_T = 1.7141 + \log S - 15.673/A_T - 2 \log A_T. \qquad (2\text{-}0)$$

This equation is the derivative of equation 0-7. Equation 2-0 is solved for the middle of the year to get close estimate of the year's growth.

Calculate 1-year volume growth of stand after first CT, given total age and site index:

$$\log V = 1.9628 - 12.4083/A_T - 1.7408/(A_B)^{0.25} + 1.3176 \log S\ (0.9);$$

$$\text{so } \log dV/dA = \log V + \log 2.3026 + \log(12.4083/(A_T)^2 + 0.4352/(A_B)^{1.25}).$$

$$\log dV_A = \log\ (1.12 + 0.0105\ A_T - 0.00005 A_T{}^2);$$

$$\text{if } (A_T \text{ GT } 105),\ \log dV_A = 0.22304.$$

Combining the last two equations gives:

$$\log d\hat{V}/dA = \log dV_A + \log dV/dA. \qquad (2\text{-}1)$$

This equation uses equation 0-1 to get the b.h. age, given total age.

The derivative of equation 0-9 was compared with Staebler's[6] and Curtis'[7] estimates of gross growth for ages 30 to 100 and adjusted (by use of log dV_A) to approximate gross growth ratios. With a better data base, an interaction of adjustment by site might show up.

Calculate adjustment to volume growth, given total age of first CT:

$$V_A = (405 - A_T)/400. \qquad (2\text{-}2)$$

This equation reduces growth by 0.25 percent for each year CT is delayed. If CT is scheduled at age 25, the growth would be 95 percent of full growth. This allowance is made because crowns become progressively less able to respond to release as first CT age increases.

Calculate competition growth reduction multiplier, given ratio of average basal area of living merchantable trees to top limit of basal area in natural stand (G_Z):

$$V_A = (1-16(G_Z - 0.5)^4). \qquad (2\text{-}3)$$

The ratio G_Z is calculated for every period of growth ($G_Z = G_M/G_L$). G_L comes from equation 1-0. The reduction multiplier has little effect on growth until stand density is considerably above average for dense natural stands. If a thinning schedule is assumed that includes a long period after an early CT on a good site, the stand will progress to above average density. Thinned stands will probably grow better than natural stands at these high densities for a while, and then in a dry summer lose groups of trees to mortality. It was simpler merely to slow diameter growth than to simulate a hypothetical pattern of mortality. The growth reduction multiplier also reduces growth in open stands. This symmetrical function gives an approximation of the plateau of maximum yield hypothesized for stands of different densities.

VOLUME FUNCTIONS

The expression $V/G = f(\bar{H}_D)$ is the main control over total cubic-foot volume of natural stands in the simulator, and the expression $dV/dA = f(A_T, A_C, S)$ controls total volume growth. Other volume functions estimate total volume of stand components and merchantable volume.

Calculate tarif diameter function, given diameter:

$$F = (0.004978\bar{D}_G^{\,2})/(0.005454(\bar{D}_G^{\,2} + 16)(1.0378 + 1.4967(0.0134^{(\bar{D}_G/10)})) - 0.1745). \qquad (3\text{-}0)$$

---

[6] Staebler, George R. 1955. Gross yield and mortality tables for fully stocked stands of Douglas-fir. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn. Res. Pap. 14, 20 p., illus. Portland, Oreg.

[7] Curtis, Robert O. 1967. A method of estimation of gross yield of Douglas-fir. For. Sci. Monogr. 13, 24 p., illus.

This equation is used in various ways in the program in the relation T = F*V/G (where T is Washington Department of Natural Resources tarif).[8] When V/G is predicted from $\bar{H}_D$ and $\bar{D}_G$ from total age and site, a stand tarif can be calculated. Then, if a $\bar{D}_G$ for a stand component is estimated, the corresponding V/G can be calculated. This relation is approximate, not exact, and is applied generally to smallest stand components so the error in volume is minimized. Volumes of larger stand components are estimated from volume of total stand and volume of small components.

Height growth of submerchantable trees is calculated from their V/G on the basis of average of current stand tarif and tarif at first CT.

Calculate stand mean height, given average height of dominants and codominants, and total number of trees per acre:

$$\bar{H}_M = \bar{H}_D * (3040 - N)/3000; \tag{3-1}$$

$$\text{if } (\bar{H}_M \text{ GT } \bar{H}_D),\ \bar{H}_M = \bar{H}_D.$$

This equation is based on $\bar{H}_M = 0.8\ \bar{H}_D$ for 640 trees per acre, and $\bar{H}_M = \bar{H}_D$ for 40 trees. Mean heights for components of stand are obtained by adjusting this value by relations between V/G ratios.

Calculate cubic volume to a 4-inch top (CV4), given total cubic volume, stand diameter, and mean height:

$$C_U = 0.8758 + 0.001049\bar{H}_M - 0.000002824\bar{H}_M^{\,2} + 0.3221/\bar{D}_G - 45.647/\bar{D}_G^{\,3}. \tag{3-2}$$

The relation CV4 = C_U*V appears in the program and completes merchantable volume calculation.

Calculate International 1/4-inch volume to a 5-inch top (IV5), given total cubic volume, stand diameter, and mean height:

$$C_I = 2.408 + 0.04633\bar{H}_M - 0.0001082\bar{H}_M^{\,2} + 31.058/\bar{D}_G^{\,2} - 10.675\bar{H}_M/\bar{D}_G^{\,3}. \tag{3-3}$$

The relation IV5 = C_I*V appears in the program.

Calculate Scribner volume to a 6-inch top (SV6), given total cubic volume, stand diameter, and mean height:

$$C_S = 1.728 + 0.05048\bar{H}_M - 0.0001192\bar{H}_M^{\,2} - 78.562/\bar{D}_G^{\,2} - 1.0166\bar{H}_M/\bar{D}_G^{\,2}. \tag{3-4}$$

The relation SV6 = C_S*CVT appears in the program.

---

[8] Turnbull, K. J., Gene Roy Little, and Gerald E. Hager. 1963. Comprehensive tree-volume tarif tables. State Wash., Dep. Nat. Resour., 23 p., illus.

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                                             TABLE 1

                                          PROGRAM  DFIT

                                DOUGLAS-FIR MANAGED YIELD TABLES

                                          SITE INDEX=140.0 (100-YEAR BASIS)
      THE CONTROL CARD SPECIFIES THAT
           DIAMETER OF THE MERCHANTABLE PART OF THE STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  8.00 INCHES.
           THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
           THE STAND HAS NOT HAD A PRECOMMERCIAL THINNING.
           THE THINNING INTERVAL IS  10 YEARS.
           NUMBER OF COMMERCIAL THINNINGS=  2.
           TOTAL AGE AT HARVEST=  60 YEARS.
           HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
           THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
           DISCCUNT RATE= .0600 .


       DOM +                                                   *                                         *          G 1/
TOTAL  CODOM                      MEAN    MEAN    MEAN         *        VOLUME     PER     ACRE          *  TREES    PER   CURRENT     DISC      CUM
AGE   HEIGHT       STAND           DBH     G 1/    VCL   VOL/G1/            4-INCH    5-INCH 2/  6-INCH *    PER   ACRE     PRICE    PRICE    PRICE
YEARS  FEET      COMPONENT      INCHES   SQ FT   CU FT   RATIO *   CU FT     CU FT  INTL 1/4   SCRIB2/ *   ACRE  SQ FT         $        $        $
 35.9   73.5  FIRST POSS           7.00   .2673    7.52   28.15 *   4826                                  *   641.5  171.4

  36    73.7  TOTAL BEFCRE         7.02   .2687    7.58   28.20 *   4841      4054      17484       8916 *   639.0  171.7
              SUBMERCH             4.89   .1303    3.12   23.92 *    738       440        872            *   236.8   30.9

              MERCHANTABLE         8.01   .3502   10.20   29.14 *   4103      3614      16612       8916 *   402.1  140.8     1337     1337     1337
              CUT                  8.01   .3497   10.19   29.13 *   1367      1204       5533       2967 *   134.2   46.9      356      356
              MERCH LEAVE          8.02   .3504   10.21   29.14 *   2736      2409      11079       5949 *   267.9   93.9
              TOTAL LEAVE          6.73   .2471    6.88   27.85 *   3474      2850      11950       5949 *   504.7  124.7

              SUM GROSS                                         *   4841      4054      17484       8916 *          171.7
              SUM MERCH                                         *   4103      3614      16612       8916 *          140.8
              SUM OF CUT           8.01                         *   1367      1204       5533       2967 *   134.2   46.9


              VOL GROWTH                                        *   2322                                  *
              SUBMERCH MORT        4.82   .1266    3.00   23.72 *    504       292        525            *   167.9   21.3

  46    91.6  TOTAL BEFORE         9.27   .4687   15.71   33.51 *   5291      4856      25264      17705 *   336.9  157.9
              SUBMERCH             5.05   .1393    3.56   25.54 *    245       157        222            *    69.0    9.6

              MERCHANTABLE        10.07   .5535   18.84   34.03 *   5046      4699      25042      17705 *   267.9  148.3     2656     1483     1839
              CUT                  9.19   .4602   15.32   33.30 *   1343      1234       6338       4228 *    87.6   40.3      507      283
              MERCH LEAVE         10.48   .5989   20.54   34.30 *   3703      3465      18703      13477 *   180.3  108.0
              TOTAL LEAVE          9.30   .4717   15.84   33.58 *   3948      3622      18926      13477 *   249.2  117.6

              SUM GROSS                                         *   7163      6353      31323      20672 *          226.1
              SUM MERCH                                         *   6414      5903      30575      20672 *          195.2
              SUM OF CUT           8.49                         *   2711      2438      11872       7195 *   221.9   87.3


              VOL GROWTH                                        *   2861                                  *
              SUBMERCH MORT        4.98   .1354    3.43   25.34 *    163       102        121            *    47.5    6.4

  60   110.1  TOTAL BEFORE        12.49   .8503   32.94   38.74 *   6646      6349      37827      30349 *   201.8  171.6
              SUBMERCH             5.21   .1480    4.02   27.16 *     86        58         73            *    21.5    3.2

              MERCHANTABLE        13.09   .9341   36.39   38.96 *   6560      6290      37754      30349 *   180.3  168.4     4552     1124     1764

  60   110.1  HARVEST             13.09   .9341   36.39   38.96 *   6560      6290      37754      30349 *   180.3  168.4

 GRAND TOTALS

              SUM GROSS                                         *  10023      9181      50345      37544 *          286.5
              SUM MERCH                                         *   9270      8729      49626      37544 *          255.6
              SUM OF CUT          10.80                         *   9270      8729      49626      37544 *   402.1  255.6
```

1/ Basal area.

2/ Board feet.

SUBMERCHANTABLE TREES AND MORTALITY

Calculate number of submerchantable trees per acre in a natural stand, given the mean diameter of a natural stand of current age and site and the minimum merchantable diameter:

$$\log N_s = 3.8622 + 3.1994 \log D_m - 4.70 \log \bar{D}_G. \qquad (4\text{-}0)$$

This equation is used for natural stands both with and without CT. Equation 4-1 must be changed if equation 4-0 is.

Calculate basal area per acre of submerchantable trees in a natural stand, given the mean diameter of a natural stand of current age and site and the minimum merchantable diameter:

$$\log G_s = 1.4034 + 4.9394 \log D_m - 4.44 \log \bar{D}_G. \qquad (4\text{-}1)$$

This equation is used for natural stands both with and without CT. Differences between estimates at successive ages give submerchantable mortality between those ages. Equations 0-5, 0-6, 0-7, and 0-8 are used to calculate net vital statistics of natural stands at successive ages. Equation 2-1 gets gross volume growth. Given these values and an estimate of submerchantable mortality, the merchantable mortality can be estimated. If equation 4-1 is changed, equation 4-0 must be changed too.

PRECOMMERCIAL THINNING ADJUSTMENTS

Calculate adjusted site index for superior height growth after PCT, given site index before PCT:

$$S_P = S\ (1 + (210 - S)^2/90000). \qquad (5\text{-}0)$$

$$\text{if (S GT 210), SP = S.}$$

This equation increases site index for the growth stimulation between PCT and first CT. In this period number of trees is assumed to be reduced to a level that promotes rapid growth. Improved vigor of the stand is assumed to last indefinitely. This function can be modified.

Calculate age at first possible CT for_stands PCT to about 400 trees per acre, given total age (based on 8-inch $\bar{D}_M$ and adjusted site index) and age at PCT:

$$\text{if } (A_P \text{ GE 15 and } A_P \text{ LE 20}),$$

$$A_F = A_T\ (0.68 + 0.016A_P).$$

$$\text{if } (A_P \text{ GE 2 and } A_P \text{ LE 14}),$$

$$A_F = A_T\ (0.8244 + 0.004333\ AP/10 + 0.0150(AP/10)^2 + 0.01667\ (AP/10)^3). \qquad (5\text{-}1)$$

When age at PCT is under 20 years, these equations reduce age at first possible CT. The greatest possible reduction--for PCT at 2 years, used to estimate plantation growth--is to 83 percent of age at CT without PCT.

Calculate adjusted basal area per acre in PCT stand with less than 400 trees per acre, at the age when a 400-tree stand would average 8 inches, given the average diameter of merchantable trees at first possible CT:

$$G_S = 180.22 - 5\ \bar{D}_F. \qquad (5\text{-}2)$$

This equation controls the growth of stands whose average merchantable diameter at first possible CT is greater than 8 inches. DFIT calculates and reports number of trees per acre at age of first CT in such stands. DFIT grows these stands to desired size from adjusted basal area. The number of trees per acre in these stands is stated for age at first CT. The number left after PCT may be greater than this if mortality is anticipated.

COMMERCIAL THINNING

Calculate ratio of diameter cut to diameter merchantable stand before CT, given minimum merchantable diameter and present merchantable diameter:

$$d/D = (4/7)(1 + D_m/\bar{D}_M); \qquad (6\text{-}0)$$

$$\text{if } (d/D \text{ LT } 0.8),\ d/D = 0.8.$$

This calculation sets d/D at 1.0 when CT is same date as first possible CT and drops it to 0.8 when the average merchantable diameter is about double the merchantable diameter at first possible CT. A constant d/D can be selected by entering it in columns 55 to 59 of control card 1. For other d/D this equation can be changed.

Calculate two-thirds of merchantable basal area per acre before CT and use the result as the limit to residual basal area from equation 1-3:

$$G_K = (2/3)*G_M, \qquad (6\text{-}1)$$

$$\text{if } (G_R \text{ LT } G_K),\ G_R = G_K.$$

This expression is used as the limit in the first CT. A similar limit is imposed on second and subsequent CT's where it would be effective only with extremely long thinning intervals.

FERTILIZER ADJUSTMENT

Calculate adjusted site index and use it to calculate growth during the 10-year period after 200 pounds of nitrogen per acre are applied, given site index before fertilization:

$$\log S_N = \log S + 0.7590 \log ((830 - S)/600); \qquad (7\text{-}0)$$

$$\text{if } (\log S_N \text{ LT } \log S),\ \log S_N = \log S.$$

This equation makes the following adjustments for each of the 10 years after fertilization:

S	S_N	dV multiplier
80	94.76	1.25
110	126.33	1.20
140	155.67	1.15
170	182.75	1.10
200	207.55	1.05

The equation implies no gain at or above site 230. This might give unreasonable answers if controls also call for large genetic gains on high sites. Volume increment gains are distributed between diameter and height growth by changing the site index to get the assumed increase in volume increment. This improves height increment, and the diameter (basal area) improvement is based on the volume-basal area ratio appropriate to the attained height. Increment returns to initial site index after 10 years.

GROWTH ADJUSTMENT

Calculate an adjusted site index that changes total volume growth, given unadjusted site index and user selected increase or decrease in growth.

$$\log S_A = \log S + (\log (1 + R/100))/1.3176 \qquad (8\text{-}0)$$

This equation changes site index used to calculate growth or yield. It is applied to equations 0-1 through 0-9 when a change in growth affecting both natural and managed stands is assumed. It is used in equation 5-0 for early growth of planted or PCT stands. Finally, it can be used in equations 2-0 and 2-1 to change growth of managed stand after first CT.

Changing Functions

Several of the functions just discussed can be changed without upsetting internal relations in DFIT. If changes are made, the user should remember that the program as written was balanced against observed growth on thinned plots, and changes may upset this balance. The first three changes discussed below are for thinning controls and can be fairly large without upsetting balance of DFIT.

Basal area after first CT is limited to two-thirds the basal area before thinning or to a recommended level based on average merchantable diameter before thinning. The two-thirds limit for first CT is easily changed by adjusting equation 6-1.

To change the recommended basal area level after thinning, replace equations 1-3 and 1-4 with any equations involving only average diameter and basal area. Most competition indexes can be altered to a per-acre relation of this kind.

The ratio of average diameter cut to average diameter of merchantable trees before thinning can be changed to a fixed value by use of control columns 55-59. If a changing ratio is wanted, equation 6-0 can be replaced with any other relation expressing d/D as a function of merchantable diameter limit and current average merchantable diameter.

Fertilizer effects for 10-year periods are easily changed by replacing equation 7-0. The coefficient of the adjusting term in equation 7-0 (0.7590) is the reciprocal of the coefficient of the site term in equation 0-9 (1.3176).

Estimates of merchantable volume can be changed by altering equations 3-1 through 3-4. Equations 3-2 to 3-4 express the ratio of merchantable volume to total volume as a function of mean tree height and mean tree diameter.

Other functions can be changed as indicated in the discussion of the function list.

It is also possible to add features to the program by internal modification. Several such modifications have been made since the first draft of this paper was written. A list of other modifications suggests the need for a choice between early publication of a useful simulator and later publication of a more nearly perfect simulator. The former has been selected, and suggested modifications are listed below:

1. Controlling period between thinnings based on basal area growth.

2. Listing of mean annual increment and periodic annual increment at each thinning date for managed stands.

3. Cumulating mortality and reporting both net and gross m.a.i. and p.a.i. for natural stands.

4. Controlling IV5 so DFIT will report either International 1/4-inch or International 1/8-inch rule.

5. Controlling value so stumpage can be based on any measure of volume (not just Scribner).

6. Ten years after fertilization, changing site to that indicated by attained tree height.

7. Stand description supplied by user.

8. Estimating yields of understocked stands with densities between PCT and natural stands. The adjusted ages and sites of such stands at first CT would be between those of PCT and natural stands.

9. Estimating yields of extremely open stands.

10. Introducing one or more stochastic elements such as: volume increment, suppression mortality, d/D ratio, g/G ratio.

11. Adjusting growth rate for any specified period.

Only the 7th to 11th modifications require much more than programing time. To modify DFIT to accept a wide range of stand conditions would require inclusion of growth limiters appropriate to such a range and development of suitable descriptors for abnormal conditions.

Appendix

SYMBOLS

A	Stand age (years)
C	Total cubic-foot volume adjuster
CT	Commercial thinning
CV4	Cubic volume to 4-inch top, no stump (cubic feet)
CVT	Total cubic volume (cubic feet)
d/D	Ratio diameter cut to diameter before thinning.
D	Diameter (inches)
$\bar{D}$	Average diameter (inches)
DFIT	Douglas-fir interim tables
F	Diameter function
g/G	Ratio basal area per acre cut to basal area before thinning
G	Basal area per acre (square feet)
GE	Greater than or equal
$\bar{H}$	Mean height (feet)
IV5	International 1/4-inch board-foot volume to 5-inch top
N	Number of trees per acre
PCT	Precommercial thinning
R	Change in growth rate
S	Site index (100-year basis)
SV6	Scribner formula board-foot volume to 6-inch top
T	Department of Natural Resources tarif
V	Total cubic-foot volume per acre
V/G	Volume to basal area ratio (feet)
$\hat{V}$	Adjusted volume

SUBSCRIPTS

A	Adjusted or adjuster
B	Breast high
C	Commercial thinning
D	Dominant and codominant
F	First possible
G	Basal area
I	International log rule
K	Limit
L	Limit
m	Merchantable limit
M	Merchantable (or mean in mean height)
N	Nitrogen fertilizer
P	Precommercial thinning
R	Recommended
s	Submerchantable
S	Scribner log rule
T	Total
U	Cubic volume
Z	Ratio

TABLE 1A

SUMMARY TABLE

TOTAL AGE YEARS	DOM + CODOM HEIGHT FEET	STAND COMPONENT	MEAN DBH INCHES	VOLUME PER ACRE CU FT	4-INCH CU FT	5-INCH INTL 1/4[1]	6-INCH SCRIB[1]	TREES PER ACRE	G[2] PER ACRE
36	74	TOTAL BEFORE	7.02	4841	4054	17484	8916	639.0	171.7
		MERCHANTABLE	8.01	4103	3614	16612	8916	402.1	140.8
46	92	TOTAL BEFORE	9.27	5291	4856	25264	17705	336.9	157.9
		MERCHANTABLE	10.07	5046	4699	25042	17705	267.9	148.3
60	110	TOTAL BEFORE	12.49	6646	6349	37827	30349	201.8	171.6
		MERCHANTABLE	13.09	6560	6290	37754	30349	180.3	168.4

NATURAL STAND TABLE

SITE INDEX=140.0 (100-YEAR BASIS)

TOTAL AGE YEARS	DOM + CODOM HEIGHT FEET	STAND COMPONENT	MEAN DBH INCHES	MEAN G[2] SQ FT	MEAN VOL CU FT	VOL/G[2] RATIO	VOLUME PER ACRE CU FT	4-INCH CU FT	5-INCH INTL 1/4[1]	6-INCH SCRIB[1]	TREES PER ACRE	G[2] PER ACRE SQ FT	CURRENT PRICE $	DISC PRICE $
36	73.7	TOTAL	7.02	.2687	7.58	28.20	4841	4054	17484	8916	639.0	171.7		
		SUBMERCH	4.89	.1303	3.12	23.92	738	440	872		236.8	30.9		
		MERCHANTABLE	8.01	.3502	10.20	29.14	4103	3614	16612	8916	402.1	140.8	1337	1337
		SUBMERCH MORT	4.82	.1266	3.00	23.72	504	292	525		167.9	21.3		
		MERCH MORT	6.79	.2513	7.35	29.25	295	245	1011	388	40.2	10.1		
46	91.6	TOTAL	9.13	.4542	15.22	33.51	6559	5999	30740	20967	430.9	195.7		
		SUBMERCH	5.05	.1393	3.56	25.59	246	157	248		69.0	9.6		
		MERCHANTABLE	9.71	.5142	17.44	33.92	6313	5842	30492	20967	361.9	186.1	3145	1756
		SUBMERCH MORT	4.98	.1354	3.44	25.39	163	102	139		47.5	6.4		
		MERCH MORT	7.63	.3176	10.61	33.41	917	808	3697	2064	86.4	27.5		
60	110.1	TOTAL	11.69	.7458	28.89	38.74	8581	8159	47504	37072	297.0	221.5		
		SUBMERCH	5.21	.1480	4.04	27.33	87	59	81		21.5	3.2		
		MERCHANTABLE	12.05	.7925	30.83	38.90	8494	8100	47422	37072	275.5	218.3	5561	1373

[1] Board feet.

[2] Basal area

TABLE 2

```
                                         PROGRAM  DFIT

                               DOUGLAS-FIR MANAGED YIELD TABLES

                                     SITE INDEX=140.0 (100-YEAR BASIS)
      THE CONTROL CARD SPECIFIES THAT
           DIAMETER OF THE MERCHANTABLE PART OF THE STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS 10.00 INCHES.
           THE MINIMUM MERCHANTABLE DBH IS  7.50 INCHES.
           THE STAND HAS NOT HAD A PRECOMMERCIAL THINNING.
           THE THINNING INTERVAL IS  10 YEARS.
           NUMBER OF COMMERCIAL THINNINGS=  2.
           TOTAL AGE AT HARVEST=  60 YEARS.
           HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
           THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
           DISCOUNT RATE= .0600.

                                                                                                  G1/
    DOM +                                               *                                 *
TOTAL CODOM                   MEAN    MEAN    MEAN      *       VOLUME   PER   ACRE       *  TREES  PER   CURRENT  DISC    CUM
AGE  HEIGHT      STAND        DBH     G1/     VOL    VOL/G1/          4-INCH   5-INCH 2/ 6-INCH *   PER  ACRE   PRICE   PRICE   PRICE
YEARS  FEET    COMPONENT     INCHES   SQ FT   CU FT  RATIO *  CU FT   CU FT  INTL 1/4  SCRIB 2/ *  ACRE  SQ FT     $       $       $
 44.1  88.6  FIRST POSS        8.75  .4176   13.63  32.64 *  6255                             *  459.0 191.6

  45   90.1  TOTAL BEFORE      8.93  .4346   14.36  33.05 *  6398    5815    29305    19426  *  445.4 193.6
             SUBMERCH          6.12  .2045    5.95  29.07 *   929     732     2523      626  *  156.2  31.9

             MERCHANTABLE     10.12  .5588   18.91  33.84 *  5469    5083    26782    18800  *  289.2 161.6   2820    2820    2820
             CUT              10.07  .5531   18.69  33.80 *  1821    1691     8896     6227  *   97.4  53.9    747     747
             MERCH LEAVE      10.15  .5618   19.02  33.86 *  3648    3391    17885    12574  *  191.8 107.7
             TOTAL LEAVE       8.58  .4014   13.15  32.76 *  4577    4123    20409    13200  *  348.0 139.7

             SUM GROSS                                  *  6398    5815    29305    19426  *        193.6
             SUM MERCH                                  *  5469    5083    26782    18800  *        161.6
             SUM OF CUT       10.07                     *  1821    1691     8896     6227  *   97.4  53.9


             VOL GROWTH                                 *  2060                             *
             SUBMERCH MORT     6.02  .1975    5.70  28.86 *   530     412     1369      281  *   93.0  18.4

  55  104.2  TOTAL BEFORE     10.88  .6455   23.95  37.10 *  6107    5755    32611    24883  *  255.0 164.6
             SUBMERCH          6.28  .2148    6.54  30.45 *   414     334     1143      389  *   63.2  13.6

             MERCHANTABLE     12.02  .7875   29.69  37.70 *  5694    5421    31468    24494  *  191.8 151.0   3674    2052    2799
             CUT              11.15  .6783   25.22  37.19 *  1139    1079     6137     4646  *   45.2  30.6    557     311
             MERCH LEAVE      12.27  .8211   31.06  37.83 *  4554    4342    25332    19849  *  146.6 120.4
             TOTAL LEAVE      10.82  .6384   23.67  37.08 *  4968    4676    26475    20237  *  209.9 134.8

             SUM GROSS                                  *  8458    7859    42877    31391  *        236.9
             SUM MERCH                                  *  7515    7112    40364    30721  *        204.9
             SUM OF CUT       10.42                     *  2960    2770    15033    10872  *  142.6  84.5


             VOL GROWTH                                 *   947                             *
             SUBMERCH MORT     6.13  .2052    6.19  30.16 *   128      95      308       89  *   19.3   4.0

  60  110.1  TOTAL BEFORE     12.00  .7852   30.42  38.74 *  5796    5520    32673    26011  *  190.5 149.6
             SUBMERCH          6.34  .2190    6.78  38.97 *   298     243      831      310  *   43.9   9.6

             MERCHANTABLE     13.23  .9547   37.49  39.27 *  5498    5277    31842    25701  *  146.6 140.0   3855    1609    2667

  60  110.1  HARVEST          13.23  .9547   37.49  39.27 *  5498    5277    31842    25701  *  146.6 140.0

 GRAND TOTALS

             SUM GROSS                                  *  9406    8798    49383    37254  *        256.5
             SUM MERCH                                  *  8458    8047    46875    36573  *        224.5
             SUM OF CUT       11.93                     *  8458    8047    46875    36573  *  289.2 224.5
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[1] Basal area.   [2] Board feet.

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                                          TABLE 3

                                       PROGRAM  DFIT

                               DOUGLAS-FIR MANAGED YIELD TABLES

                                       SITE INDEX=140.0 (100-YEAR BASIS)
          THE CONTROL CARD SPECIFIES THAT
                THE FIRST COMMERCIAL THINNING WILL OCCUR WHEN TOTAL AGE IS  40 YEARS.
                DIAMETER OF THE TOTAL STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  7.00 INCHES.
                THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
                THE STAND HAS NOT HAD A PRECOMMERCIAL THINNING.
                THE THINNING INTERVAL IS  10 YEARS.
                NUMBER OF COMMERCIAL THINNINGS=  2.
                TOTAL AGE AT HARVEST=  60 YEARS.
                HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
                THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
                DISCOUNT RATE= .0600.

       DOM +                                                 *                                         *       G 1/
TOTAL CODOM                      MEAN   MEAN    MEAN         *        VOLUME   PER   ACRE              *  TREES  PER   CURRENT  DISC   CUM
AGE  HEIGHT       STAND          DBH    G 1/    VOL   VOL/G 1/         4-INCH   5-INCH     6-INCH      *   PER  ACRE    PRICE   PRICE  PRICE
YEARS  FEET     COMPONENT      INCHES  SQ FT   CU FT  RATIO  *  CU FT   CU FT  INTL 1/4 2/ SCRIB 2/    *  ACRE  SQ FT     $       $      $
 35.9  73.5    FIRST POSS        7.00  .2673    7.52  28.15  *  4826                                   * 641.5 171.4

  40   81.5    TOTAL BEFORE      7.89  .3398   10.38  30.53  *  5558    4885    22858      13662       * 535.7 182.0
               SUBMERCH          4.96  .1343    3.31  24.64  *   451     278      492                  * 136.3  18.3

               MERCHANTABLE      8.67  .4100   12.79  31.19  *  5107    4607    22367      13662       * 399.3 163.7    2049    2049   2049
               CUT               6.38  .3833   11.85  30.91  *  1687    1511     7218       4258       * 142.4  54.6     511     511
               MERCH LEAVE       8.83  .4248   13.31  31.33  *  3420    3097    15149       9403       * 256.9 109.2
               TOTAL LEAVE       7.71  .3241    9.84  30.37  *  3871    3374    15641       9403       * 393.3 127.5

               SUM GROSS                                     *  5558    4885    22858      13662       *       182.0
               SUM MERCH                                     *  5107    4607    22367      13662       *       163.7
               SUM OF CUT        8.38                        *  1687    1511     7218       4258       * 142.4  54.6


               VOL GROWTH                                    *  2204                                   *
               SUBMERCH MORT     4.88  .1301    3.18  24.42  *   284     170      263                  *  89.3  11.6

  50   97.6    TOTAL BEFORE      9.96  .5410   19.05  35.22  *  5792    5391    29207      21313       * 304.0 164.4
               SUBMERCH          5.11  .1422    3.71  26.13  *   175     114      155                  *  47.0   6.7

               MERCHANTABLE     10.61  .6140   21.86  35.60  *  5617    5277    29052      21313       * 256.9 157.8    3197    1785   2296
               CUT               9.49  .4913   17.07  34.74  *  1558    1444     7621       5265       *  91.3  44.9     632     353
               MERCH LEAVE      11.18  .6816   24.50  35.95  *  4058    3833    21431      16048       * 165.6 112.9
               TOTAL LEAVE      10.15  .5623   19.90  35.40  *  4233    3947    21587      16048       * 212.7 119.6

               SUM GROSS                                     *  7762    7071    36688      25571       *       230.6
               SUM MERCH                                     *  7304    6787    36270      25571       *       212.3
               SUM OF CUT        8.83                        *  3245    2955    14839       9523       * 233.7  99.4


               VOL GROWTH                                    *  1975                                   *
               SUBMERCH MORT     5.02  .1373    3.55  25.88  *    91      58       62                  *  25.5   3.5

  60  110.1    TOTAL BEFORE     12.44  .8439   32.69  38.74  *  6118    5844    34853      27975       * 187.1 157.9
               SUBMERCH          5.21  .1480    4.02  27.17  *    86      58       71                  *  21.5   3.2

               MERCHANTABLE     13.09  .9342   36.41  38.98  *  6031    5785    34781      27975       * 165.6 154.7    4196    1308   2172

  60  110.1    HARVEST          13.09  .9342   36.41  38.98  *  6031    5785    34781      27975       * 165.6 154.7

  GRAND TOTALS

               SUM GROSS                                     *  9737    9026    50016      37498       *       272.5
               SUM MERCH                                     *  9277    8740    49620      37498       *       254.2
               SUM OF CUT       10.80                        *  9277    8740    49620      37498       * 399.3 254.2
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1/ Basal area. 2/ Board feet.

TABLE 4

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                                        PROGRAM  DFIT

                              DOUGLAS-FIR MANAGED YIELD TABLES

                                        SITE INDEX=140.0 (100-YEAR BASIS)
   THE CONTROL CARD SPECIFIES THAT
         THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
         THE STAND WAS PRECOMMERCIALLY THINNED AT AGE   10 YEARS.
         THE THINNING INTERVAL IS  10 YEARS.
         NUMBER OF COMMERCIAL THINNINGS=  2.
         TOTAL AGE AT HARVEST=  60 YEARS.
         HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
         THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
         DISCOUNT RATE= .0600.

         SITE INDEX WAS ADJUSTED TO 147.6 BECAUSE OF PRECOMMERCIAL THINNING.


       DOM +                                                  *                                         *         G 1/
TOTAL  CODOM                      MEAN   MEAN    MEAN         *          VOLUME   PER   ACRE            *  TREES   PER  CURRENT    DISC     CUM
AGE   HEIGHT       STAND          DBH    G 1/    VOL VOL/G 1/ *            4-INCH     5-INCH     6-INCH *    PER   ACRE   PRICE   PRICE   PRICE
YEARS   FEET      COMPONENT     INCHES  SQ FT   CU FT   RATIO *  CU FT      CU FT INTL 1/4 2/   SCRIB 2/ *   ACRE  SQ FT       $       $       $
 29.5   62.2    FIRST POSS        8.00  .3491    8.61   24.66 *   3458                                  *  401.7 140.2

   30   63.6    MERCHANTABLE      8.11  .3585    9.00   25.09 *   3614       3179      14502       7655 *  401.7 144.0     1148    1148    1148
                CUT               8.06  .3544    8.88   25.05 *   1203       1056       4808       2517 *  135.4  48.0      302     302
                MERCH LEAVE       8.13  .3606    9.06   25.11 *   2411       2123       9695       5138 *  266.3  96.0

                SUM GROSS                                     *   3614       3179      14502       7655 *        144.0
                SUM MERCH                                     *   3614       3179      14502       7655 *        144.0
                SUM OF CUT        8.06                        *   1203       1056       4808       2517 *  135.4  48.0


                VOL GROWTH                                    *   2666                                  *

   40   85.9    MERCHANTABLE     10.48  .5989   19.07   31.84 *   5078       4734      25140      17947 *  266.3 159.5     2692    1503    1805
                CUT               9.42  .4836   15.03   31.09 *   1476       1357       6948       4649 *   98.1  47.5      558     312
                MERCH LEAVE      11.05  .6662   21.42   32.16 *   3602       3377      18192      13298 *  168.1 112.0

                SUM GROSS                                     *   6280       5791      29948      20464 *        207.5
                SUM MERCH                                     *   6280       5791      29948      20464 *        207.5
                SUM OF CUT        8.66                        *   2678       2413      11756       7166 *  233.6  95.5


                VOL GROWTH                                    *   4599                                  *

   60  116.0    MERCHANTABLE     14.88 1.2074   48.78   40.40 *   8201       7917      49206      41005 *  168.1 203.0     6151    1071    1684

   60  116.0    HARVEST          14.88 1.2074   48.78   40.40 *   8201       7917      49206      41005 *  168.1 203.0

 GRAND TOTALS

                SUM GROSS                                     *  10879      10330      60962      48170 *        298.5
                SUM MERCH                                     *  10879      10330      60962      48170 *        298.5
                SUM OF CUT       11.67                        *  10879      10330      60962      48170 *  401.7 298.5
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1/ Basal area.

2/ Board feet.

TABLE 5

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                                                PROGRAM  DFIT

                                    DOUGLAS-FIR MANAGED YIELD TABLES

                                             SITE INDEX=140.0 (100-YEAR BASIS)
THE CONTROL CARD SPECIFIES THAT
      DIAMETER OF THE MERCHANTABLE PART OF THE STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  8.00 INCHES.
      THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
      THE STAND WAS PRECOMMERCIALLY THINNED AT AGE   10 YEARS.
      THE THINNING INTERVAL IS CONTROLLED BY HEIGHT GROWTH. THERE WILL BE APPROXIMATELY 25.0 FEET OF
        HEIGHT GROWTH BETWEEN COMMERCIAL THINNINGS.
      NUMBER OF COMMERCIAL THINNINGS=  2.
      TOTAL AGE AT HARVEST=  60 YEARS.
      HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
      THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
      DISCOUNT RATE= .0600.

      SITE INDEX WAS ADJUSTED TO 147.6 BECAUSE OF PRECOMMERCIAL THINNING.


      DOM +                                              *                                      *         G1/
TOTAL CODOM                    MEAN   MEAN   MEAN        *    VOLUME    PER    ACRE             *  TREES   PER  CURRENT     DISC     CUM
AGE  HEIGHT      STAND          DBH    G1/   VOL  VOL/G1/          4-INCH    5-INCH      6-INCH *   PER  ACRE    PRICE     PRICE   PRICE
YEARS  FEET   COMPONENT      INCHES  SQ FT  CU FT  RATIO *  CU FT     CU FT INTL 1/4 2/ SCRIB2/ *  ACRE  SQ FT      $         $       $
 29.5   62.2  FIRST POSS       8.00  .3491   8.61  24.66 *   3458                               *  401.7 140.2

   30   63.6  MERCHANTABLE     8.11  .3585   9.00  25.09 *   3614      3179     14502      7655 *  401.7 144.0     1148     1148    1148
              CUT              8.06  .3544   8.88  25.05 *   1203      1056      4808      2517 *  135.4  48.0      302      302
              MERCH LEAVE      8.13  .3606   9.06  25.11 *   2411      2123      9695      5138 *  266.3  96.0

              SUM GROSS                                  *   3614      3179     14502      7655 *        144.0
              SUM MERCH                                  *   3614      3179     14502      7655 *        144.0
              SUM OF CUT       8.06                      *   1203      1056      4808      2517 *  135.4  48.0


              VOL GROWTH                                 *   3172                               *

   42   89.7  MERCHANTABLE    10.80  .6365  20.97  32.94 *   5583      5231     28305     20650 *  266.3 169.5     3098     1539    1841
              CUT              9.60  .5028  16.15  32.11 *   1736      1604      8344      5703 *  107.5  54.0      684      340
              MERCH LEAVE     11.55  .7270  24.23  33.33 *   3848      3628     19961     14948 *  158.8 115.4

              SUM GROSS                                  *   6786      6288     33113     23167 *        217.5
              SUM MERCH                                  *   6786      6288     33113     23167 *        217.5
              SUM OF CUT       8.78                      *   2938      2660     13152      8219 *  242.9 102.1


              VOL GROWTH                                 *   4094                               *

   60  116.0  MERCHANTABLE    15.07 1.2379  50.01  40.40 *   7942      7669     47780     39931 *  158.8 196.6     5990     1043    1685

   60  116.0  HARVEST         15.07 1.2379  50.01  40.40 *   7942      7669     47780     39931 *  158.8 196.6

   GRAND TOTALS

              SUM GROSS                                  *  10880     10329     60932     48151 *        298.6
              SUM MERCH                                  *  10880     10329     60932     48151 *        298.6
              SUM OF CUT      11.67                      *  10880     10329     60932     48151 *  401.7 298.6
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[1] Basal area.

[2] Board feet.

TABLE 6

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                                            PROGRAM  DFIT

                                  DOUGLAS-FIR MANAGED YIELD TABLES

                                          SITE INDEX=140.0 (100-YEAR BASIS)
        THE CONTROL CARD SPECIFIES THAT
             DIAMETER OF THE TOTAL STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  8.00 INCHES.
             THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
             THE STAND WAS PRECOMMERCIALLY THINNED AT AGE   10 YEARS.
             THE THINNING INTERVAL IS  10 YEARS.
             NUMBER OF COMMERCIAL THINNINGS=  2.
             TOTAL AGE AT HARVEST=  60 YEARS.
             FERTILIZER (NITROGEN 200 LB/ACRE) IS APPLIED AT EACH COMMERCIAL THINNING.
             HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
             THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
             DISCOUNT RATE= .0600.

             SITE INDEX WAS ADJUSTED TO 147.6 BECAUSE OF PRECOMMERCIAL THINNING.


      DOM +                                                *                                          *         G 1/
TOTAL CODOM                         MEAN    MEAN    MEAN       *         VOLUME   PER    ACRE              *  TREES  PER  CURRENT   DISC    CUM
AGE  HEIGHT       STAND             DBH      G 1/   VOL      VOL/G 1/ *          4-INCH   5-INCH     6-INCH   *   PER   ACRE   PRICE   PRICE   PRICE
YEARS  FEET     COMPONENT          INCHES  SQ FT   CU FT    RATIO *   CU FT    CU FT  INTL 1/4 2/ SCRIB 2/ *  ACRE  SQ FT     $       $       $
 29.5  62.2    FIRST POSS           8.00   .3491    8.61   24.66 *   3458                                  *  401.7 140.2

  30   63.6    MERCHANTABLE         8.11   .3585    9.00   25.09 *   3614      3179     14502      7655    *  401.7 144.0    1148    1148    1148
               CUT                  8.06   .3544    8.88   25.05 *   1203      1056      4808      2517    *  135.4  48.0     302     302
               MERCH LEAVE          8.13   .3606    9.06   25.11 *   2411      2123      9695      5138    *  266.3  96.0

               SUM GROSS                                         *   3614      3179     14502      7655    *        144.0
               SUM MERCH                                         *   3614      3179     14502      7655    *        144.0
               SUM OF CUT           8.06                         *   1203      1056      4808      2517    *  135.4  48.0


               VOL GROWTH                                        *   3033                                  *

  40   88.2    MERCHANTABLE        10.74   .6289   20.45   32.51 *   5444      5094     27399     19879    *  266.3 167.5    2982    1665    1967
               CUT                  9.56   .4990   15.82   31.70 *   1671      1542      7983      5424    *  105.7  52.7     651     363
               MERCH LEAVE         11.44   .7144   23.49   32.88 *   3773      3552     19416     14455    *  160.6 114.7

               SUM GROSS                                         *   6647      6150     32207     22395    *        215.5
               SUM MERCH                                         *   6647      6150     32207     22395    *        215.5
               SUM OF CUT           8.75                         *   2874      2599     12791      7941    *  241.1 108.7


               VOL GROWTH                                        *   4933                                  *

  60  120.1    MERCHANTABLE        15.47  1.3058   54.20   41.51 *   8706      8424     53175     44792    *  160.6 209.7    6719    1170    1835

  60  120.1    HARVEST             15.47  1.3058   54.20   41.51 *   8706      8424     53175     44792    *  160.6 209.7

  GRAND TOTALS

               SUM GROSS                                         *  11580     11023     65966     52733    *        310.5
               SUM MERCH                                         *  11580     11023     65966     52733    *        310.5
               SUM OF CUT          11.90                         *  11580     11023     65966     52733    *  401.7 310.5
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[1] Basal area.

[2] Board feet.

TABLE 7

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                                                   PROGRAM  DFIT

                                      DOUGLAS-FIR MANAGED YIELD TABLES

                                                 SITE INDEX=140.0 (100-YEAR BASIS)
     THE CONTROL CARD SPECIFIES THAT
          THE FIRST COMMERCIAL THINNING WILL OCCUR WHEN TOTAL AGE IS  40 YEARS.
          DIAMETER OF THE MERCHANTABLE PART OF THE STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  8.00 INCHES.
          THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
          THE STAND WAS PRECOMMERCIALLY THINNED AT AGE   10 YEARS.
          THE THINNING INTERVAL IS  10 YEARS.
          NUMBER OF COMMERCIAL THINNINGS=  2.
          TOTAL AGE AT HARVEST=  60 YEARS.
          HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
          THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
          DISCOUNT RATE= .0600.

          SITE INDEX WAS ADJUSTED TO 147.6 BECAUSE OF PRECOMMERCIAL THINNING.


                                                                                                         G1/
     DOM +                                                 *                                          *
TOTAL CODOM                     MEAN   MEAN   MEAN         *       VOLUME   PER   ACRE                *  TREES  PER  CURRENT   DISC    CUM
AGE  HEIGHT      STAND           DBH    G1/   VCL   VOL/G1/*             4-INCH   5-INCH      6-INCH  *   PER  ACRE   PRICE   PRICE   PRICE
YEARS  FEET    COMPONENT      INCHES  SQ FT  CU FT  RATIO  *   CU FT     CU FT  INTL 1/4 2/  SCRIB2/  *  ACRE SQ FT     $       $       $
29.5   62.2   FIRST POSS        8.00  .3491   6.61  24.66  *   3458                                   *  401.7 140.2

 40    85.9   MERCHANTABLE      9.47  .4892  15.58  31.84  *   6257      5752     29331      19580   *  401.7 196.5   2937    2937    2937
              CUT               8.84  .4263  13.34  31.30  *   2050      1863      9231       5840   *  153.7  65.5    701     701
              MERCH LEAVE       9.84  .5282  16.96  32.11  *   4207      3889     20100      13740   *  248.0 131.0

              SUM GROSS                                    *   6257      5752     29331      19580   *        196.5
              SUM MERCH                                    *   6257      5752     29331      19580   *        196.5
              SUM OF CUT        8.84                       *   2050      1863      9231       5840   *  153.7  65.5


              VOL GROWTH                                   *   2362                                   *

 50   102.9   MERCHANTABLE     11.50  .7210  26.48  36.73  *   6568      6229     35566      27181   *  248.0 178.8   4077    2277    2977
              CUT              10.00  .5453  19.47  35.70  *   1707      1597      8707       6252   *   87.7  47.8    750     419
              MERCH LEAVE      12.24  .8171  30.32  37.10  *   4861      4632     26860      20930   *  160.3 131.0

              SUM GROSS                                    *   8619      8092     44797      33021   *        244.3
              SUM MERCH                                    *   8619      8092     44797      33021   *        244.3
              SUM OF CUT        9.28                       *   3758      3460     17937      12091   *  241.4 113.3


              VOL GROWTH                                   *   2118                                   *

 60   116.0   MERCHANTABLE     14.05 1.0773  43.52  40.40  *   6979      6728     41559      34202   *  160.3 172.7   5130    1600    2719

 60   116.0   HARVEST          14.05 1.0773  43.52  40.40  *   6979      6728     41559      34202   *  160.3 172.7

 GRAND TOTALS

              SUM GROSS                                    *  10736     10188     59496      46294   *        286.1
              SUM MERCH                                    *  10736     10188     59496      46294   *        286.1
              SUM OF CUT       11.43                       *  10736     10188     59496      46294   *  401.7 286.1
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[1/] Basal area.

[2/] Board feet.

TABLE 8

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                                                   PROGRAM  DFIT

                                      DOUGLAS-FIR MANAGED YIELD TABLES

                                                 SITE INDEX=140.0 (100-YEAR BASIS)
THE CONTROL CARD SPECIFIES THAT
      THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
      THE STAND WAS PLANTED.
      THE THINNING INTERVAL IS  10 YEARS.
      NUMBER OF COMMERCIAL THINNINGS=  2.
      TOTAL AGE AT HARVEST=  60 YEARS.
      HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
      THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
      DISCOUNT RATE= .0600.

      SITE INDEX WAS ADJUSTED TO 147.6 BECAUSE THE STAND WAS PLANTED.


                                                                                            G 1/
      DOM +                                                *                          *
OTAL CODOM                  MEAN   MEAN   MEAN           1/       VOLUME  PER  ACRE              *  TREES  PER   CURRENT  DISC   CUM
GE  HEIGHT      STAND       DBH    G 1/   VOL   VOL/G  *          4-INCH   5-INCH    2/  6-INCH  *   PER   ACRE   PRICE  PRICE  PRICE
EARS  FEET    COMPONENT    INCHES  SQ FT  CU FT RATIO  *  CU FT   CU FT  INTL 1/4   SCRIB 2/  *  ACRE  SQ FT    $       $      $
 28.3  59.1   FIRST POSS    8.00  .3491   8.27  23.69 *  3321                                 *  401.7 140.2

 29   61.0    MERCHANTABLE  8.15  .3623   8.80  24.28 *  3534    3107    14107      7384  *  401.7 145.5   1108    1108   1108
              CUT           8.09  .3566   8.64  24.23 *  1175    1031     4668      2415  *  136.0  48.5    290     290
              MERCH LEAVE   8.18  .3652   8.88  24.31 *  2359    2076     9439      4969  *  265.7  97.0

              SUM GROSS                               *  3534    3107    14107      7384  *        145.5
              SUM MERCH                               *  3534    3107    14107      7384  *        145.5
              SUM OF CUT    8.09                      *  1175    1031     4668      2415  *  136.0  48.5


              VOL GROWTH                              *  2694                             *

 39   83.9    MERCHANTABLE 10.56  .6083  19.02  31.26 *  5052    4709    24895     17766  *  265.7 161.6   2665    1488   1778
              CUT           9.46  .4884  14.90  30.51 *  1488    1368     6979      4660  *   99.9  48.8    559     312
              MERCH LEAVE  11.17  .6805  21.50  31.59 *  3564    3341    17916     13106  *  165.8 112.8

              SUM GROSS                               *  6228    5740    29563     20181  *        210.1
              SUM MERCH                               *  6228    5740    29563     20181  *        210.1
              SUM OF CUT    8.70                      *  2664    2399    11647      7074  *  235.9  97.3


              VOL GROWTH                              *  4869                             *

 60  116.0    MERCHANTABLE 15.19 1.2589  50.86  40.40 *  8433    8144    50748     42478  *  165.8 208.7   6372    1047   1649

 60  116.0    HARVEST      15.19 1.2589  50.86  40.40 *  8433    8144    50748     42478  *  165.8 208.7

 GRAND TOTALS

              SUM GROSS                               * 11097   10543    62396     49552  *        306.0
              SUM MERCH                               * 11097   10543    62396     49552  *        306.0
              SUM OF CUT   11.82                      * 11097   10543    62396     49552  *  401.7 306.0
```

[1] Basal area.

[2] Board feet.

TABLE 9

```
                                   PROGRAM  DFIT

                         DOUGLAS-FIR MANAGED YIELD TABLES

                                   SITE INDEX=140.0 (100-YEAR BASIS)
THE CONTROL CARD SPECIFIES THAT
     DIAMETER OF THE TOTAL STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  8.00 INCHES.
     THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
     THE STAND WAS PLANTED.
     THE THINNING INTERVAL IS  10 YEARS.
     NUMBER OF COMMERCIAL THINNINGS=  2.
     TOTAL AGE AT HARVEST=  60 YEARS.
     HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
     THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
     DISCOUNT RATE= .0600.
     STAND VOLUME GROWTH WILL BE INCREASED  20.0 PERCENT STARTING AT PLANTING.
     SITE INDEX WAS ADJUSTED TO 160.8 TO SIMULATE THIS GROWTH CHANGE.

     SITE INDEX WAS ADJUSTED TO 165.1 BECAUSE THE STAND WAS PLANTED.


       DOM +                                             *                                           *         G1/
TOTAL CODOM                       MEAN    MEAN    MEAN   *        VOLUME     PER    ACRE             *  TREES  PER   CURRENT     DISC      CUM
 AGE  HEIGHT      STAND           DBH     G1/     VOL    VOL/G1/*           4-INCH   5-INCH 2/  6-INCH  *   PER  ACRE    PRICE    PRICE    PRICE
YEARS  FEET     COMPONENT       INCHES   SQ FT   CU FT   RATIO *  CU FT     CU FT  INTL 1/4  SCRIB2/  *  ACRE SQ FT      $        $        $
 25.1  56.4   FIRST POSS          8.00   .3491    7.96   22.81 *  3198                                 *  401.7 140.2

  26   59.1   MERCHANTABLE        8.21   .3675    8.70   23.68 *  3496      3075     13922     7272   *  401.7 147.6     1091     1091     1091
              CUT                 8.12   .3596    8.49   23.61 *  1162      1019      4596     2362   *  136.9  49.2      283      283
              MERCH LEAVE         8.25   .3716    8.81   23.72 *  2335      2056      9326     4910   *  264.8  98.4

              SUM GROSS                                        *  3496      3075     13922     7272   *        147.6
              SUM MERCH                                        *  3496      3075     13922     7272   *        147.6
              SUM OF CUT          8.12                         *  1162      1019      4596     2362   *  136.9  49.2


              VOL GROWTH                                       *  3202                                 *

  36   86.9   MERCHANTABLE       10.92   .6505   20.91   32.14 *  5537      5184     27878    20332   *  264.8 172.3     3050     1703     1986
              CUT                 9.67   .5099   15.97   31.31 *  1742      1609      8329     5678   *  109.1  55.6      681      380
              MERCH LEAVE        11.72   .7491   24.37   32.53 *  3794      3575     19549    14654   *  155.7 116.6

              SUM GROSS                                        *  6699      6203     32474    22694   *        221.5
              SUM MERCH                                        *  6699      6203     32474    22694   *        221.5
              SUM OF CUT          8.84                         *  2904      2628     12925     8040   *  246.0 104.9


              VOL GROWTH                                       *  6592                                 *

  60  129.8   MERCHANTABLE       16.64  1.5110   66.70   44.14 * 10387     10098     65724    56396   *  155.7 235.3     8459     1167     1831

  60  129.8   HARVEST            16.64  1.5110   66.70   44.14 * 10387     10098     65724    56396   *  155.7 235.3

 GRAND TOTALS

              SUM GROSS                                        * 13291     12725     78649    64435   *        340.2
              SUM MERCH                                        * 13291     12725     78649    64435   *        340.2
              SUM OF CUT         12.46                         * 13291     12725     78649    64435   *  401.7 340.2
```

[1] Basal area.

[2] Board feet.

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1977

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EFFECTS OF THINNING ON YIELD OF DOUGLAS-FIR:

CONCEPTS AND SOME ESTIMATES OBTAINED BY SIMULATION

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Abstract

Observation and research on yields of managed Douglas-fir stands have given us many bits of knowledge, but no unified picture. We assembled these fragmented bits of knowledge into a conceptual model of stand structure and development, which provides a basis for extrapolating results of studies to conditions which have not been directly observed. A stand simulator (DFIT) provides details on number and size of trees and distribution of yield over time. Details and operation of DFIT are described in a companion paper. This paper discusses concepts of stand development and effects of thinning, provides guidelines for thinning, and summarizes current expectations.

We describe structure mortality, and growth of natural stands, and use these attributes as a basis for projections. We assume that had the stand not been thinned, it would have been an "average" natural stand; but we also discuss effects of some variations around this average. The major source of gain from commerical thinning is harvest of merchantable trees otherwise lost to mortality. The two major sources of gains from precommercial thinning are (1) concentration of growth onto trees that will reach merchantable size and (2) improved height growth. The latter increases with progressively poorer site quality.

We recommend that precommercial thinning be done when leave trees are 10 to 15 feet tall and 10 to 15 years old. This will maximize the advantage of improved height growth, facilitate selection of high-quality leave-trees, and minimize possible subsequent damage to trees. If this stage has passed, there are still worthwhile opportunities, but gains will be less. Average spacing of these leave trees depends on desired tree size at the first commercial entry; the larger the required size at that time, the fewer trees that are left. If first commercial entry will be made when trees average 8 inches in d.b.h., with a minimum merchantable d.b.h. of about 6 inches, precommercial thinning should leave about 400-well-spaced trees per acre.

The first commercial thinning (or harvest) in precommercially thinned stands, should be when average d.b.h. of trees reaches the intended size. To maximize merchantable yield of stands not precommercially thinned, the first commercial thinning should be made about the time merchantable size trees begin to die. Just as number of trees left after precommercial thinning depends on desired tree size at the next entry, so does the number of trees left after the *last* commercial thinning depend on desired tree size at final harvest. But rather than reducing the stand to this number of trees at a single commercial thinning, excess trees may be carried for removal at subsequent thinnings. Thinning interval, level of growing stock, and, to a lesser extent, type of thinning may be balanced over a wide range of combinations which will give the desired end product.

Thinning shifts the trends of mean annual increment (m.a.i.), by any measure of volume, over time. Thus, relative differences among treatments depend on the age at which comparisons are made. At ages prior to culmination of m.a.i., relative gains from only commercial thinning are less than at culmination, whereas those from precommercial thinning are a little greater. After culmination, relative gains from commercial thinning are greater, whereas those from precommercial thinning are a little less.

The proportion of total usable production remaining for final harvest varies with thinning regime, but will likely be close to 70 percent of the total merchantable cubic volume produced; the other 30 percent being removed in thinnings. The proportion of board-foot production left for final harvest will be a little greater. In stands receiving only commercial thinning, this final harvest volume will likely be no more than about 85 percent of the volume that would have been harvested from the stand if it had not been thinned.

The average d.b.h. of trees cut at the final harvest in thinned stands will likely be from about 5 to 35 percent larger than that of *all* merchantable trees cut at final harvest of comparable unthinned stands. Considering the *same number* of largest trees, however, those cut at final harvest of stands which received only commercial thinning will be about the same size as those in unthinned stands; in stands that were also precommercially thinned, they will be about 10 to 15 percent larger. Increased growth of residual trees is offset by removal in thinnings of some larger-than-average trees that would otherwise be present at final harvest.

Gains in volume production from only commercial thinning *increase* with increasing site quality. The additional gain from precommercial thinning, however, is greatest on site IV and *decreases* with increasing site quality. Relative gains from commercial thinning decrease when less of the total volume is merchantable; thus, the gains are less in terms of board-foot volume than as cubic volume. The trend for gains from precommercial thinning is just the reverse--greater in terms of board-foot volume than as cubic volume. Relative gains on different site qualities also vary with the measure of volume.

KEYWORDS: Thinning (tree), thinning (precommercial), precommercial thinning, thinning (commercial), commercial thinning, growth (forest), increment, yield (forest), volume increment, increment (volume), growing stock (-increment/yield, mortality, stand development, stand structure, stands (even-aged), Douglas-fir, *Pseudotsuga menziesii*.

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Introduction

Intensive management of commercial forest acreage provides many opportunities to increase the amount of usable wood produced. To take advantage of these opportunities, we must estimate how stands will develop under various management regimes. The greatest need is for predictions which apply to the next generation: young stands that have not yet passed the precommercial thinning stage and stands that will be created when existing stands are harvested. These are the stands with the greatest opportunity for intensive management and maximum production. A secondary need is to help set management regimes for the remaining life of current stands which may be commercially thinned. The concern here is to provide for efficient transition from the current forest to the new forest. These practices will, in some cases, be quite different from those followed in subsequent forest rotations. In both cases, choice of management regimes must involve both economic and social considerations.

To estimate managed stand yields, we first assembled our fragmented bits of knowledge into a conceptual model, with assumptions regarding structure and development of natural stands and the resultant effects of thinning. This provided a basis for extrapolating results of studies to conditions not directly observed. Results of studies were balanced against development of natural stands, and against one another, to derive relationships among various stand parameters and to insure consistency. The variables and relationships examined are listed in the appendix.1/ Little of the information included in this report has been published.

We then constructed a simulator of managed stand yields (DFIT--Douglas-fir Interim Tables) which estimates expected stand development and yield, within specified limitations about stand characteristics and treatment regimes (Bruce et al. 1977). See appendix for sample DFIT printout. Within the limitations of our model, estimates of merchantable yields over a range of site quality, merchantability limits, and thinning regimes appear consistent and provide good estimates of relative gains from thinning. To the extent that yields without thinning may differ, so will yields with thinning.

Since no stands in the Pacific Northwest have been thinned regularly for 60 to 80 years, the yields estimated by the simulator are extrapolated far beyond the available data base. The extrapolations seem reasonable to the authors and several users, but this is no demonstration of their validity. The growth rates and other factors affecting yield will need revision when results of a current cooperative study of managed Douglas-fir yields are published.2/

The purpose of this paper is to clarify *concepts* regarding stand structure and development. We try to explain gains from thinning. We first describe assumed characteristics of natural stands, sources of gain from thinning, and effects of thinning on these sources of gain. From these we provide guidelines for thinning. We then illustrate and discuss results of thinning, as estimated by DFIT. We estimate tree size and volume yields for selected sites, merchantability standards, and thinning regimes; we supplement these estimates with brief discussions of effects of alternate thinning regimes. Finally, we discuss extrapolating to other stand conditions. The paper by Bruce et al. (1977) provides the information needed to use the simulator.

Natural Stands

To provide a base for evaluating effects of thinning on stand development, we describe the development of "average" natural stands. All our

---

1/ Supporting data on file at Forestry Sciences Laboratory, Olympia, Washington.

2/ Some assumptions and resulting estimates may require revision when a cooperative study of managed stand yields is completed. This study is being conducted by Robert O. Curtis, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, and James Arney, Weyerhaeuser Company, Centralia, Washington.

projections of stand development with thinning are made with the assumption that, had the stand not been thinned, it would have had these average natural stand attributes. Some characteristics of average natural stands are summarized in the following discussion and illustrations.

DESCRIPTION OF AVERAGE STANDS

The effects of site and age on ($\overline{Dg}$)[3] and on number of trees and basal area per acre are shown in figure 1.[4] $\overline{Dg}$ increases with age, number of trees decreases as $\overline{Dg}$ increases, and the resulting basal area per acre increases with age; the better the site quality, the more rapid the rate of change. The *resulting* relationship between $\overline{Dg}$, number, and basal area is shown in figure 2. For lack of clear evidence to the contrary, we assume this relationship to be independent of site and age; this defines a stand density index (Reineke 1933). The stand starts out with several thousand tree seedlings per acre. As the trees increase in size, the smaller trees are crowded out of the stand by their more vigorous neighbors. By the time the $\overline{Dg}$ of trees reaches 24 inches (61 cm), only about 100 trees per acre (247 per ha) remain.

The major effect of site index is on the *rate* of stand development; the better the site, the earlier the age at which a given $\overline{Dg}$ is reached. The relationship between height of dominant trees and other stand attributes does not appear to be independent of site, however, as has often been assumed (fig. 3). Our experience has shown that $\overline{Dg}$--and thus volume per acre--at a given dominant height varies with site index. When trees are small, $\overline{Dg}$ corresponding to a given height is slightly larger on good sites than on poor sites. As trees become larger (older), the trend is reversed; for a given height, $\overline{Dg}$ is smaller on good sites than on poor sites.

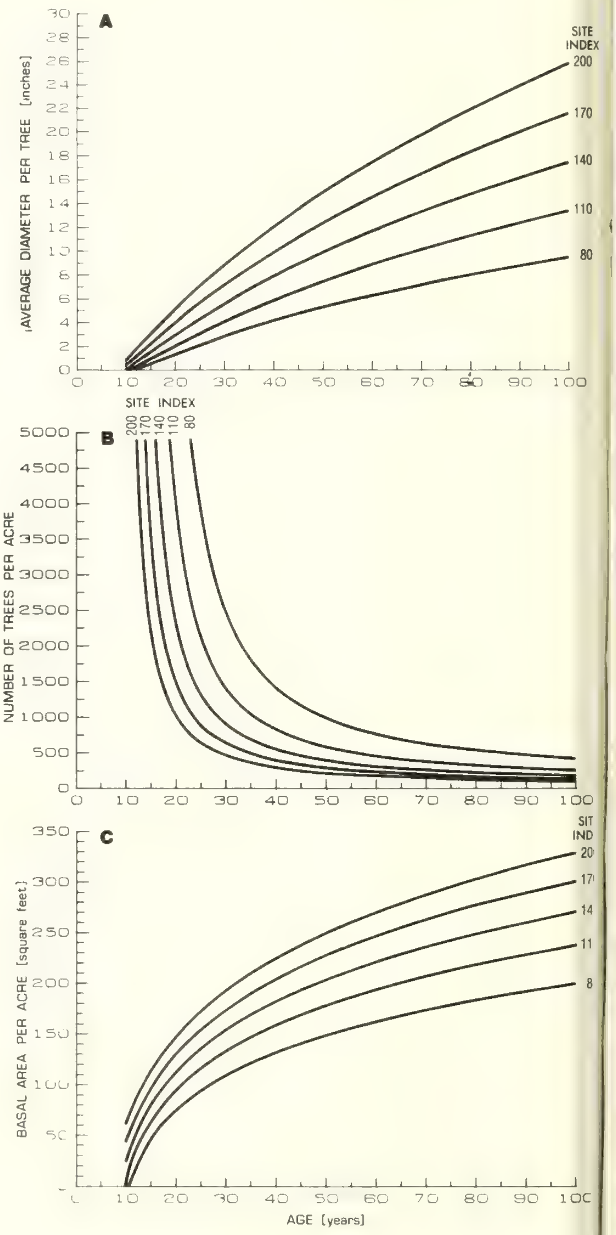


Figure 1.--Descriptors of natural stands by age and site: A, $\overline{Dg}$ of all trees; B, number of trees per acre; C, basal area per acre.

---

[3] As used throughout this paper, $\overline{Dg}$ refers to average d.b.h.; i.e., d.b.h. of a tree of mean basal area.

[4] Derived by reanalysis of data on which USDA Technical Bulletin 201 (McArdle et al. 1961) was based, plus additional data for young stands.

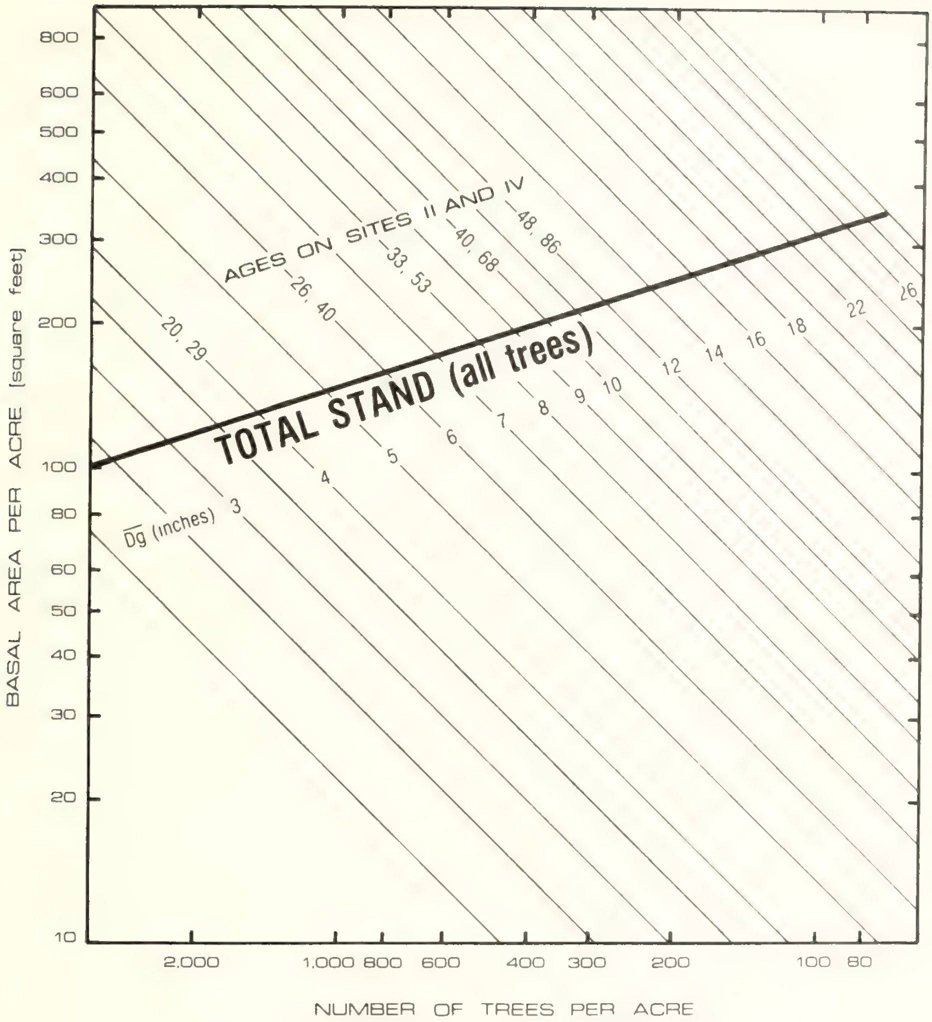


Figure 2.--Relationship among $\overline{Dg}$, number of trees, and basal area per acre in natural stands.

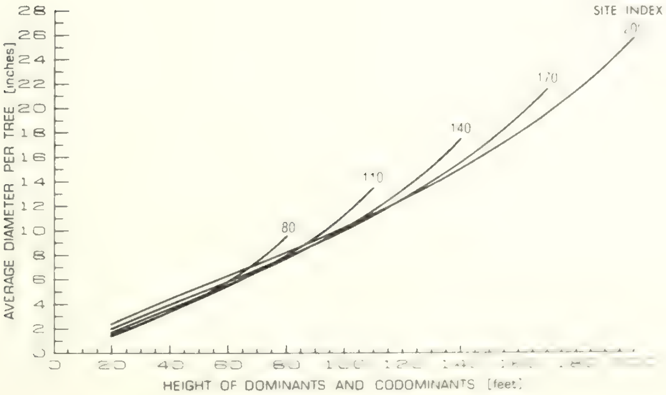


Figure 3.--Relationship between $\overline{Dg}$ and height of dominant and codominant trees in natural stands.

STAND STRUCTURE AND DEVELOPMENT

We have brought $\overline{Dg}$, number of trees, and basal area together into a single graph, as in figure 2, to facilitate examination and discussion of how stands develop over time and the effect of thinning on that development. We will build upon this figure in subsequent illustrations. In figure 2 the number of trees decreases from left to right so that the time sequence of stand development progresses in the conventional manner, from left to right. The diagonal lines, connecting points of equal $\overline{Dg}$, show the mathematical relationship among the three variables. For any combination of two of these variables, the corresponding third variable can be read for that point on the graph.

There is a wide range in size of living trees at any time. Thus, the largest third of the trees in a stand includes about 55 percent of the basal area per acre and the smallest third includes only about 15 percent of the total basal area (fig. 4A). The largest third is mostly dominants and codominants that are growing well; the smallest third is mostly suppressed trees that have nearly stopped growing. Development of the stand over time is shown in figure 4B,

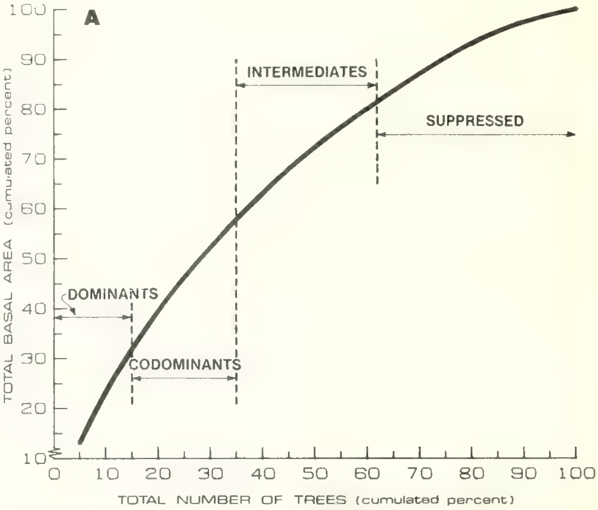
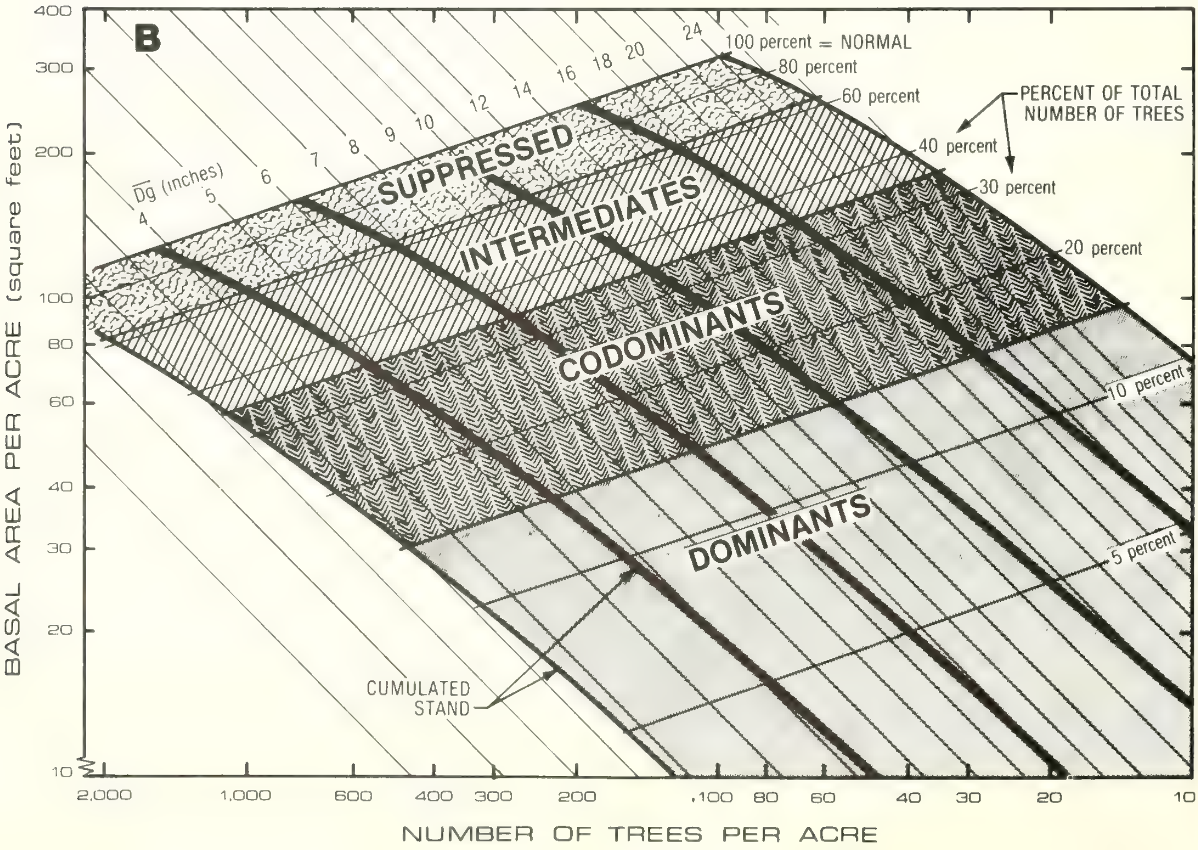


Figure 4.--Structure and development of natural stands: A, Cumulated contribution of successively smaller trees to number and basal area per acre; B, successive curves of cumulated contribution at progressively older ages.



where curves of this cumulated contribution of trees at successively older ages are plotted relative to the total number of living trees. The six curves plotted are for ages when the total numbers of trees in the stand are 3,200, 1,600, 800, 400, 200, and 100, respectively. The 100-percent curve (straight line on logarithmic scale) is the same curve shown in figure 2; this curve is traditionally called NORMAL in the United States. The portion of the stand within each crown class is the same as in figure 4A.

The development of any number of largest trees in the stand is shown by a vertical line across this sheaf of curves (fig. 5A). Thus, for example, while $\overline{Dg}$ of the total stand increases from 3.0 to 7.0 inches (7.6 to 17.8 cm)--with a loss of about 1,650 trees per acre (4,080 per ha)--$\overline{Dg}$ of the 400 largest trees per acre (990 per ha) increases from about 4.3 to 8.0 inches (10.9 to 20.3 cm).

As the stand grows, the number of trees larger than a specified minimum d.b.h. increases for a time as more trees grow to that size (fig. 5B). Eventually the smaller of these trees become suppressed and subsequently die. Thus, there

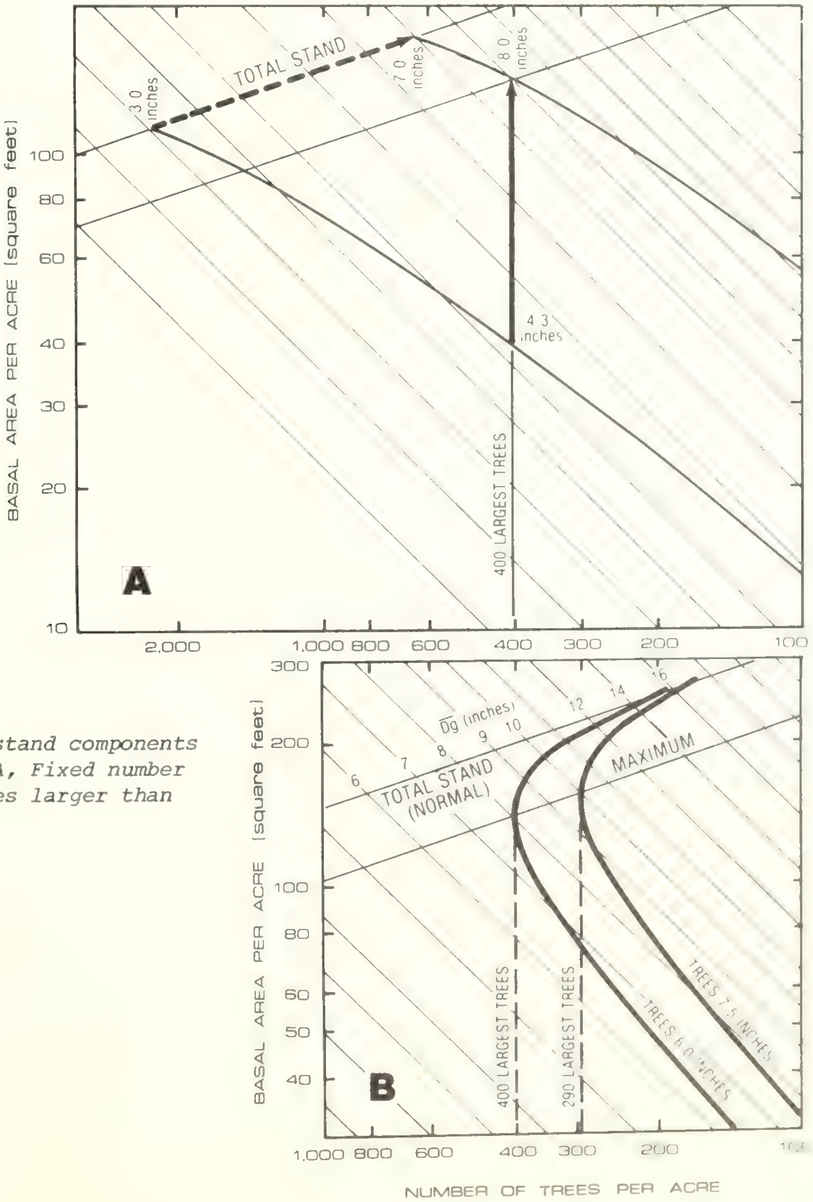


Figure 5.--Development of stand components relative to tal stand: A, Fixed number of largest trees; B, trees larger than specified d.b.h.

is a maximum number of trees that will reach any specified d.b.h. At the point where this maximum is reached, trees larger than this d.b.h. comprise about 63 percent of all trees in the stand and about 80 percent of the total basal area. We call this 63-percent curve MAXIMUM. Its importance will become more apparent in subsequent discussion. The portion of the cumulated-stand curve which is above MAXIMUM represents suppressed trees.

MORTALITY

An average natural stand loses about 1.5 percent of its trees for each 1 percent increase in $\overline{Dg}$. $\overline{Dg}$ of trees which die each year is about two-thirds the $\overline{Dg}$ of the stand. We have divided this mortality into two components--trees smaller than the specified *minimum* merchantable d.b.h. and trees larger. The latter comprise the part of mortality that can be salvaged or prevented by commercial thinning.

When the merchantable component of a natural stand reaches MAXIMUM (fig. 5B), many trees which are still alive have not yet attained the minimum merchantable size--and most of these submerchantable trees never will. Most of these submerchantable trees are suppressed and will die sporadically over an extended period. On the average, the rate at which they die is a function of the rate of stand growth; the number of live trees smaller than any specified minimum d.b.h. is a function of $\overline{Dg}$ of all trees in a natural stand (fig. 6). On good sites, most submerchantable trees will die before the time of final harvest. On poor sites, many of them will still be alive at final harvest. Volume of these small trees is similar on all sites; as a proportion of total volume produced during a rotation, such submerchantable volume is relatively minor on good sites but is substantial on poor sites.

Once the maximum number of trees larger than a specified d.b.h. is reached, merchantable trees in natural stands die at a rate which complements the submerchantable mortality (fig. 6). This merchantable mortality in natural stands is related to declining tree vigor. In thinned stands, most of these trees should be cut before they die or, at least, they should be salvaged after they die. With more growing space, the life and growth of some trees may be extended.

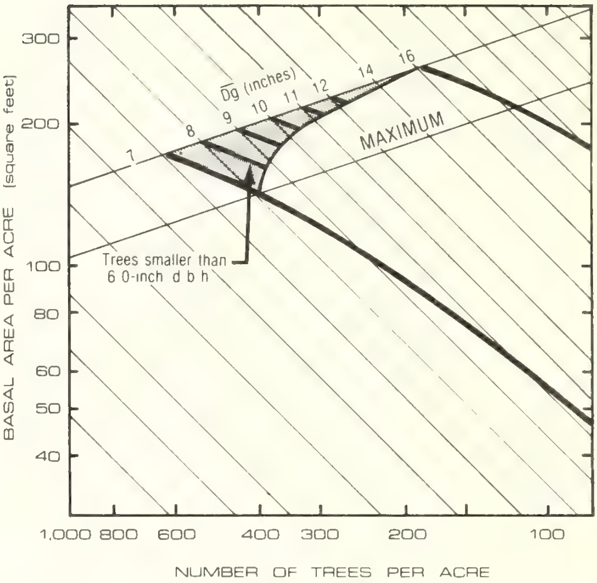


Figure 6.--Remaining number of submerchantable and merchantable trees in natural stands when minimum merchantable d.b.h. is 6.0 inches.

VARIATION AROUND AVERAGE

In reality, there is wide variation around this average natural stand. On plots from which this average was derived, number of trees at a given $\overline{Dg}$ varied from about 65 to 150 percent of the average; variation was similar for all sites and for the range of $\overline{Dg}$ included. Other plots have been observed where number of trees with a given $\overline{Dg}$ have exceeded this average by more than 50 percent, but such extreme density is not common. The reasons for the variation around the average differ from one stand to another, and each has a different effect on stand structure and development. Effects of some of these differences in stand structure will be alluded to in the section regarding extrapolation to other stand conditions.

Sources of Gain

Thinnings provide two sources of gain in usable yield: the harvest of merchantable trees which have died or soon would die and the improvement of growth rate of trees that are left. We first discuss gains (and losses) associated with commercial thinning--which is commonly a part of regimes beginning with precommercial thinning.[5] We then discuss gains associated with precommercial thinning--which we consider *added* gains relative to commercial thinning alone.

COMMERCIAL THINNING CAPTURES MERCHANTABLE MORTALITY

The major source of gain from commercial thinning is harvest of merchantable trees that would otherwise be lost to mortality. The larger the size to which trees are grown, the greater is the loss to mortality (figs. 5, 6, and 7A). Thus, loss of merchantable production without commercial thinning--and potential gain from commercial thinning--is much greater on good sites than on poor sites. If commercial thinning is started early enough, virtually all merchantable mortality can be captured. When thinning is delayed, part of the merchantable mortality occurring prior to thinning will be lost; but part can be salvaged when the stand is thinned.

Likewise, when an unthinned stand is harvested, some recent merchantable mortality can be salvaged. Thus, merchantable yield harvested from a natural stand is a little greater than net merchantable yield, and the gain from thinning is a little less than the difference between total merchantable production in the thinned stand and net merchantable yield in the unthinned.

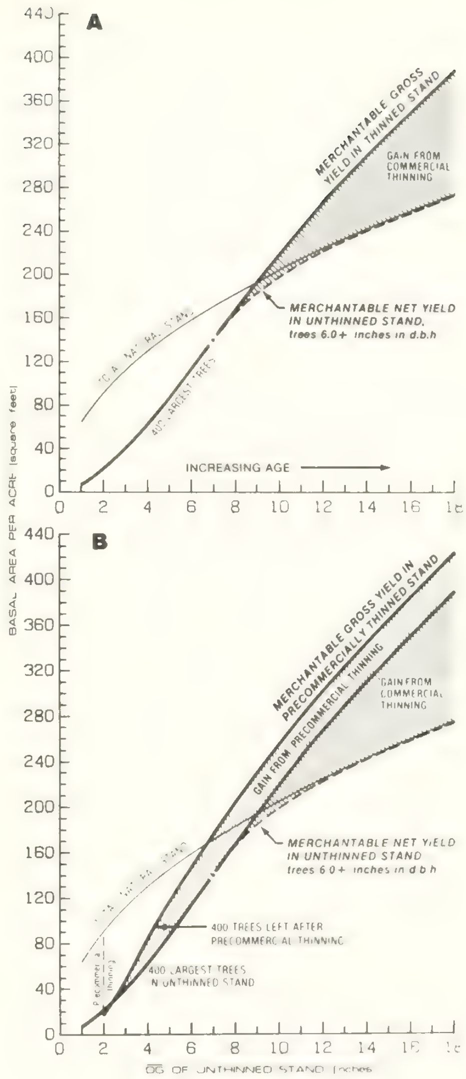


Figure 7.--Sources of gain from thinning, relative to normal stand $\overline{Dg}$: A, Capture of merchantable mortality with commercial thinnings; B, concentration of growth onto merchantable trees with precommercial thinning.

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[5] If trees are spaced widely enough, precommercially thinned stands may be carried to final harvest with no commercial thinning.

COMMERCIAL THINNING IMPROVES GROWTH OF RESIDUAL TREES

Commercial thinning also improves growth rates of individual residual trees. The gain in size of these trees, however, usually does not lead to a substantial increase in size of trees at time of final harvest. This gain is largely offset by removal of many larger-than-average trees in thinnings (Reukema 1972, Reukema and Pienaar 1973).

COMMERCIAL THINNING REDUCES CUBIC VOLUME GROWTH PER ACRE

Total cubic volume growth per acre is reduced by most thinnings because trees do not completely occupy the area after thinning. Actual trends of growth over time will vary with the thinning regime; greatest reductions, relative to potential,will be immediately after each thinning. Within fairly wide limits, however, thinning regime appears to have little effect on the *average* percentage reduction in growth over an extended period (Reukema 1972). If residual stocking is carried at a higher level, growth may be reduced a little less; if at a lower level, growth may be reduced even more. This depends, however, not only on stocking level but also on *which trees* are cut.

For lack of better information, we express this reduction in growth as a function of stand age at time of first commercial thinning; the older the stand when thinnings are begun, the greater the relative reduction in growth (fig. 8). The ability of trees to respond to release is related to their vigor which, in turn, is loosely correlated with age. At a given age, trees on good sites have relatively shorter crowns than those on poor sites, but the trees on good sites add to the size of their crowns more rapidly.

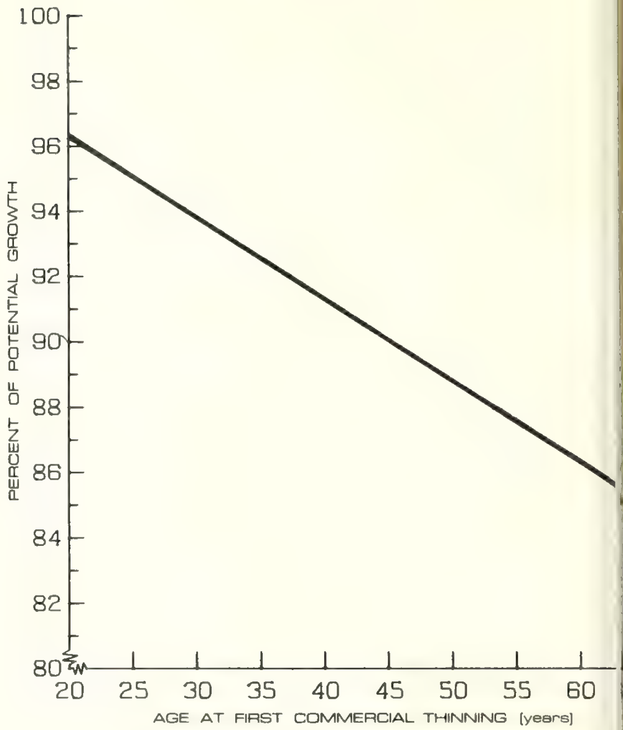

Figure 8.--Relative reduction in growth between first commercial thinning and final harvest, by age at first commercial thinning.

PRECOMMERCIAL THINNING CONCENTRATES GROWTH ON MERCHANTABLE TREES

Precommercial thinning increases growth by eliminating excess competition and concentrating all growth on trees that will become merchantable (fig. 7B). In a natural stand, as crop trees increase in size they gradually crowd out their weaker neighbors. Crop trees do not compete strongly with *one another* until their $\overline{Dg}$ approaches MAXIMUM (fig. 5B); however, a substantial part of the total stand production has been on trees that never reach merchantable size, resulting in reduced growth on trees that do. In a precommercially thinned stand, only crop trees are left. These trees do not compete strongly with one another until their $\overline{Dg}$ approaches MAXIMUM, and they reach this size sooner because of the elimination of additional competition; the earlier the precommercial thinning, the greater the gain.

If two comparable stands are precommercially thinned to different spacings, trees grown at the wider spacing will eventually reach a larger size. For a while, trees in both stands will grow at about the same rate; but as the trees increase in size, competition retards growth sooner in the stand with more trees. For example, by the time a stand with 400 trees per acre (990 per ha) reaches the MAXIMUM stocking level, trees in a stand with only 290 trees per acre (715 per ha) will be somewhat larger (fig. 9).

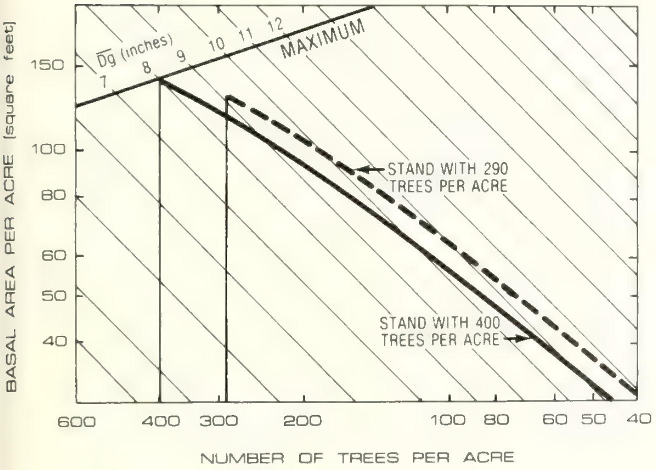

Figure 9.--Effect of spacing of trees on attained d.b.h. and on basal area per acre.

PRECOMMERCIAL THINNING IMPROVES HEIGHT GROWTH AND SITE INDEX

Precommercial thinning also improves height growth. Substantial improvement is common on poor sites (Reukema 1970); apparent short-term improvement has been observed on better-than-average sites.

Spacing apparently has little effect during the period when rate of height growth is rapidly increasing; however, in stands in which the crown canopy has not yet closed, this period of rapid height growth is prolonged. Thus, height growth in open stands culminates at a later age and at a higher rate than that in the average natural stand (fig. 10A). With a given number of trees per acre, the period to stand closure is longer on poor sites than on good sites; thus, relative improvement in height growth is greater on poor sites than on good sites. Likewise, the period to stand closure depends on stand density; the fewer the residual

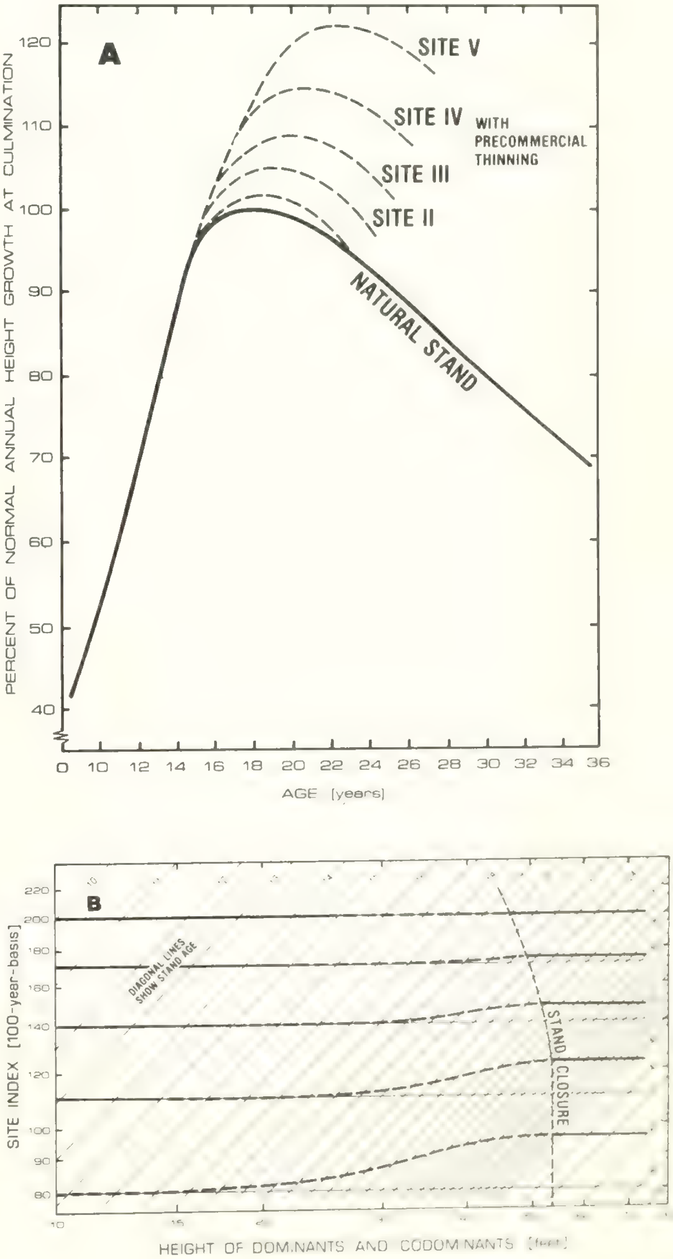

Figure 10.--Gains with precommercial thinning: A, Trends over time in height growth of dominant and codominant trees; B, improvement in site index.

trees, the longer the period. Culmination of height growth will not be delayed indefinitely on open-grown trees, so other factors must be limiting at wide spacings.

By the time the stand closes, height growth will have declined to the normal *percentage* rate and will follow the normal height growth pattern thereafter. This has the effect of improving site index up to the time of stand closure, and thereafter of maintaining it at the higher level (fig. 10B). This improvement in site index is negligible on good sites but very substantial on poor sites, where the stand may be relatively open for many years. After stand closure, the potential rate of cubic volume growth per acre appears to be about the normal rate for current site index and age, regardless of whether or not a stand was precommercially thinned (fig. 11). Thus, the inherent productivity of the site exceeds its capacity to produce under normally dense stand conditions.

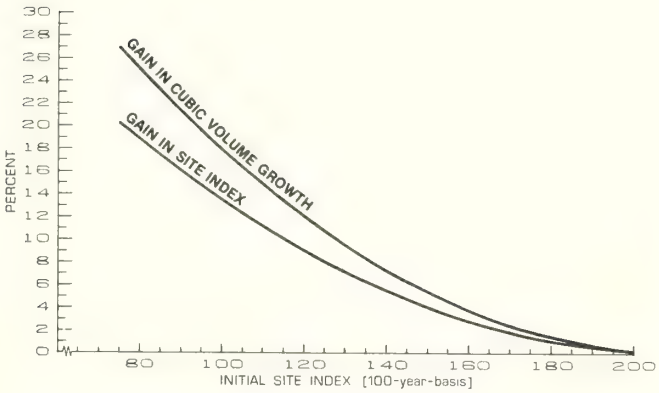

Figure 11.--Relative improvement in site index and current gross cubic volume growth with precommercial thinning.

Thinning Guidelines

The effects of thinning on stand development depend on the particular thinning regime followed. For both precommercial and commercial thinning, major considerations are: timing of thinning, average spacing of leave trees, and selection of leave trees. To help a manager select desirable thinning regimes, we discuss each of these factors. We do not try to define a "best" thinning regime, nor do we discuss all factors which the manager should consider in determining what is best for him.

PRECOMMERCIAL THINNING

Only a few highlights regarding precommercial thinning will be summarized here. We suggest that readers review "Guidelines for precommercial thinning of Douglas-fir" (Reukema 1975) for more detail.

We recommend that precommercial thinning be done when leave trees are about 10 to 15 years old and 10 to 15 feet (3 to 5 m) tall (fig. 12). This will maximize the advantage of improved

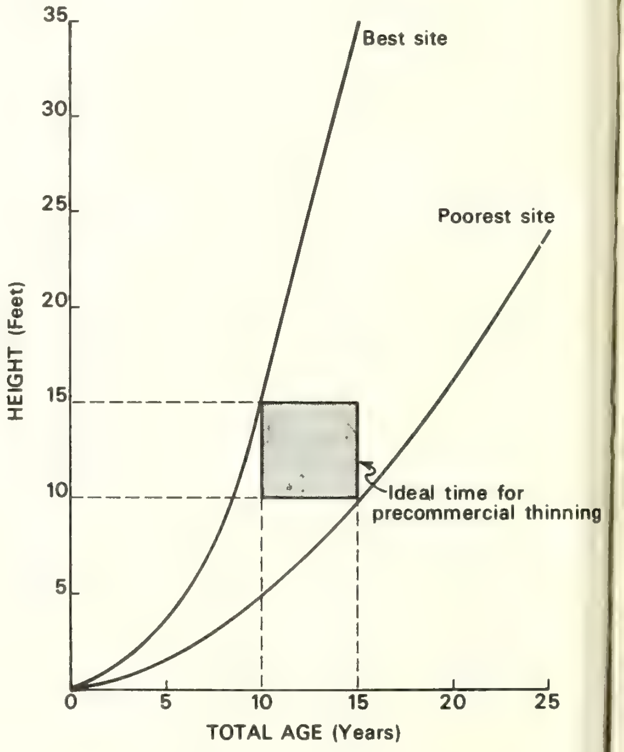

Figure 12.--Recommended time for precommercial thinning, relative to height and age of leave trees.

height growth (fig. 10), facilitate selection of high-quality leave trees, and minimize possible subsequent damage to trees. If this ideal stage has passed, there are still worthwhile opportunities for precommercial thinning; but gains will be less.

The average spacing of leave trees depends on how large the trees are expected to be when the first commercial thinning (or harvest) is made; the larger the trees at that time, the fewer the trees that are left. The number of trees to be grown to a specified size in a precommercially thinned stand is about equal to the maximum number that reach that size in the average natural stand (fig. 5B). With the spacing corresponding to this number, all trees are expected to reach merchantable size. When the desired tree size is reached, most trees will still be growing well and will respond well to release. Proper spacing is most critical on poor-quality sites.

Precommercial thinning at the recommended time should leave trees of fairly uniform size. If precommercial thinning is delayed appreciably, it may be necessary to leave a wider range of sizes. Larger trees close to merchantable size should generally be retained in the stand until the first commercial thinning.

COMMERCIAL THINNING REGIME

Just as the number of trees left after precommercial thinning depends on desired tree size at the next entry, so does the number of trees after the *last* commercial thinning depend on desired tree size at final harvest. But rather than reducing the stand to the determined number of trees at a single commercial thinning, excess trees may be left for removal at subsequent thinnings. Thinning interval, level of growing stock, and, to a lesser extent, type of thinning may be balanced over a wide range of combinations which will give the desired end product. Choice of commercial thinning regime, within wide limits, has little effect on total production; it does affect timing of yield and tree size distribution.

Desired timing of thinnings, residual stocking level, and type of thinning are so interrelated that discussing one without the others is difficult. Since they cannot all be discussed at once, we will relate each, individually, to a stocking guide (fig. 13).

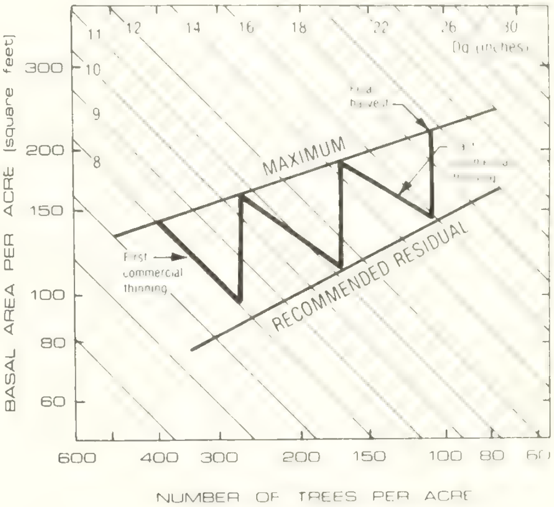

Figure 13.--A thinning regime maintaining stocking level between RECOMMENDED RESIDUAL and MAXIMUM, with maximum interval between thinnings.

MAXIMUM, as defined previously, is the approximate maximum stocking level to which a given number of merchantable trees should be grown in a managed stand. RECOMMENDED RESIDUAL is the minimum stocking level to which the merchantable portion of the stand will be reduced at each thinning; for this illustration, RECOMMENDED RESIDUAL is set at a basal area level of about 75 square feet per acre (17 m^2/ha) below MAXIMUM.

Timing of Thinning

First Thinning

To maximize usable cubic volume yield, one should make the first thinning at about the time merchantable-size trees begin to die. Therefore, first possible thinning is set at the age when the merchantable portion of the stand reaches MAXIMUM. For stands receiving only commercial thinning, this age is a function of site index and specified minimum merchantable d.b.h. For stands which have been precommercially thinned, this age is also a function of age when the stand was precommercially thinned to a specified number of trees; the earlier that stocking density is controlled, the younger the age of trees at first commercial thinning (fig. 14).

The first thinning of stands that are only commercially thinned may be delayed beyond this first possible age for thinning. This may be either a missed opportunity or the result of a management objective other than maximizing total usable yield. If thinning is delayed, merchantable trees will die out of the stand at the natural stand rate (fig. 5). The first commercial thinning of *precommercially* thinned stands should not be delayed appreciably beyond the first possible thinning age. These stands are more uniform than natural stands and are not likely to thin themselves effectively, especially on poorer sites. Instead, they may retain an excessive number of trees for a prolonged period and tend to stagnate; eventually, there likely will be heavy mortality (fig. 15).

Last Thinning

Timing of the last thinning should depend on the desired age and stand characteristics at final harvest. Generally, it would appear desirable to leave as much volume as practical for the final harvest--rather than removing more trees than necessary in thinnings. A reasonable objective would be to have the stand at MAXIMUM stocking level at time of final harvest. Once the stand has been reduced to the number of trees that are expected to reach MAXIMUM level at a desired age, another thinning is unnecessary.

Thinning Interval

If stocking is maintained between our RECOMMENDED RESIDUAL

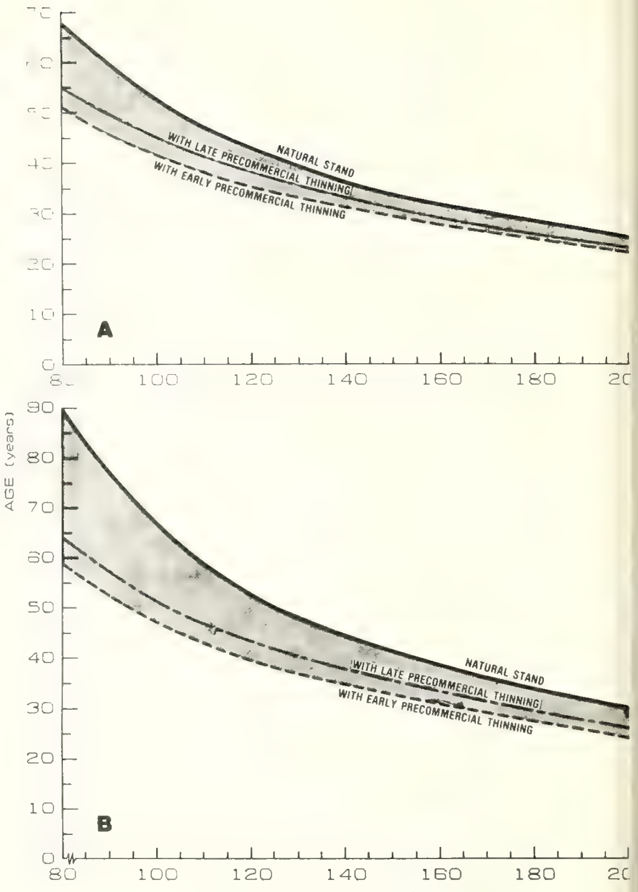

Figure 14.--Age at first possible commercial thinning, by initial site index and minimum merchantable d.b.h. (dm). A, when dm is 6.0 inches; B, when dm is 7.5 inches.

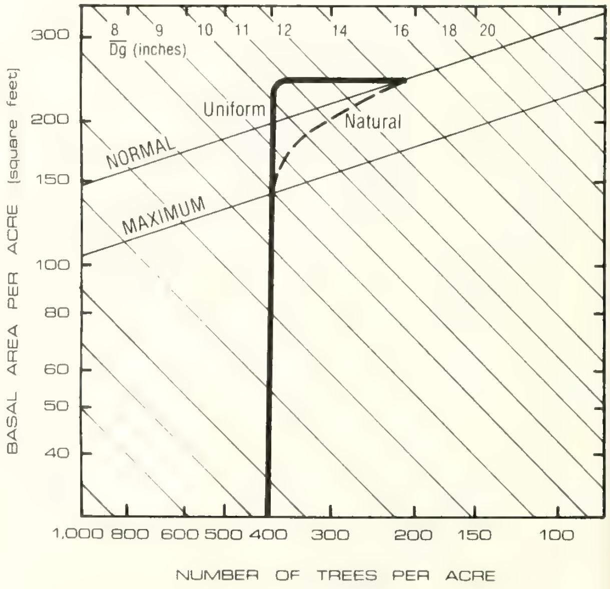

Figure 15.--Effect of delaying commercial thinning of precommercially thinned stands.

and MAXIMUM levels (fig. 13), the *maximum* interval between thinnings is the time required to grow about 75 square feet per acre (17 m^2 per ha) in basal area. If a stand is thinned more frequently, it will not build up to the MAXIMUM level, and each thinning will remove less volume. If thinnings are made less frequently, the growing stock level attained before the next thinning will exceed the MAXIMUM. If growing stock is allowed to exceed this level by very much, individual tree growth may be severely retarded.

This maximum interval can be closely approximated by fixed height growth intervals, where the interval varies by site quality--from about 24 feet (7.3 m) on site I to 15 feet (4.6 m) on site V (fig. 16). The corresponding time interval between thinnings varies substantially with site quality and stand age--from about 6 years in young site I stands to more than 30 years in site V stands (table 1). This interval can be modified to make it compatible with desired timing of the last thinning; the right-hand portion of table 1 shows an example of such a modification.

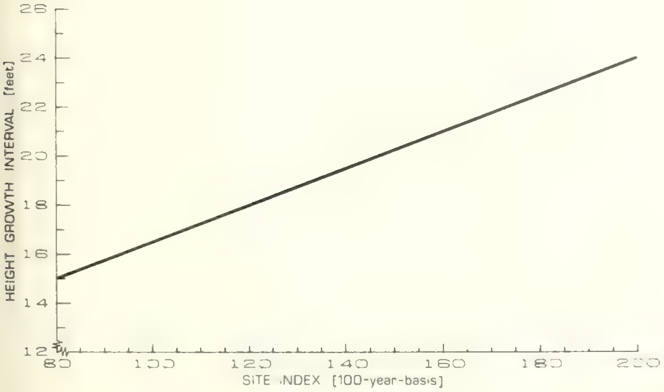

Figure 16.--Height growth interval which will maintain stocking level approximately between RECOMMENDED RESIDUAL and MAXIMUM, by site index.

Table 1--*Commercial thinning ages corresponding to suggested height-growth interval and adjusted for compatibility with rotation age, by treatment and minimum merchantable d.b.h.*

With suggested ΔH interval				Adjusted for compatibility			
CT[1] alone		PCT[2] + CT		CT alone		PCT + CT	
6.0 inches	7.5 inches	6.0 inches	7.5 inches	6.0 inches	7.5 inches	6.0 inches	7.5 inches
Site I (85 years)[3]							
25	30	22	24	25	30	22	24
32	38	28	31	32	37	28	31
40	48	36	38	40	44	34	39
51	61	45	48	51	53	42	50
65	(80)[4]	57	62	65	65	52	65
(85)	--	(74)	(81)	--	—	65	--
Site II (90 years)[3]							
30	36	26	29	30	36	26	29
38	46	33	37	39	44	33	36
49	60	43	47	51	54	42	44
64	(80)	55	61	67	67	52	53
(86)	--	(72)	(82)	—	--	67	66
Site III (95 years)[3]							
36	45	31	35	36	45	31	35
47	60	40	46	49	55	40	44
63	(82)	52	60	68	68	52	54
(86)	--	(70)	(81)	--	--	69	68
Site IV (100 years)[3]							
47	59	38	43	47	59	38	43
65	(84)	51	58	66	65	51	54
(95)	--	69	(80)	--	--	69	69
Site V (105 years)[3]							
68	(89)	51	59	68	--	51	59
(110)	--	(74)	(87)	--	--	70	70

[1] Commercial thinning.

[2] Precommercial thinning.

[3] Site class (rotation age).

[4] Numbers in parentheses are ages at completion of next ΔH thinning period.

Residual Stocking Level (Average Spacing)

At the RECOMMENDED RESIDUAL stocking level, basal area ranges from about 105 square feet per acre (24 m^2 per ha) for 10-inch (25-cm) trees to 225 square feet (51 m^2) for 30-inch (76-cm) trees; corresponding average spacings of trees are about 15 and 31 feet (4.6 and 9.4 m). We further recommend that no more than one-third of the merchantable basal area be removed in a thinning.

It would be reasonable to set residual stocking at other levels for certain situations. For example, if the time required for trees to grow from RECOMMENDED RESIDUAL to MAXIMUM (fig. 13) is longer than the thinning interval desired for a particular stand, residual stocking could be set at a higher level compatible with the shorter thinning interval (fig. 17A). On the other hand, stocking could be maintained at a lower average level (fig. 17B). In some instances, it would be reasonable to thin a stand to a stocking level below the RECOMMENDED level--with a corresponding reduction in growth per acre.

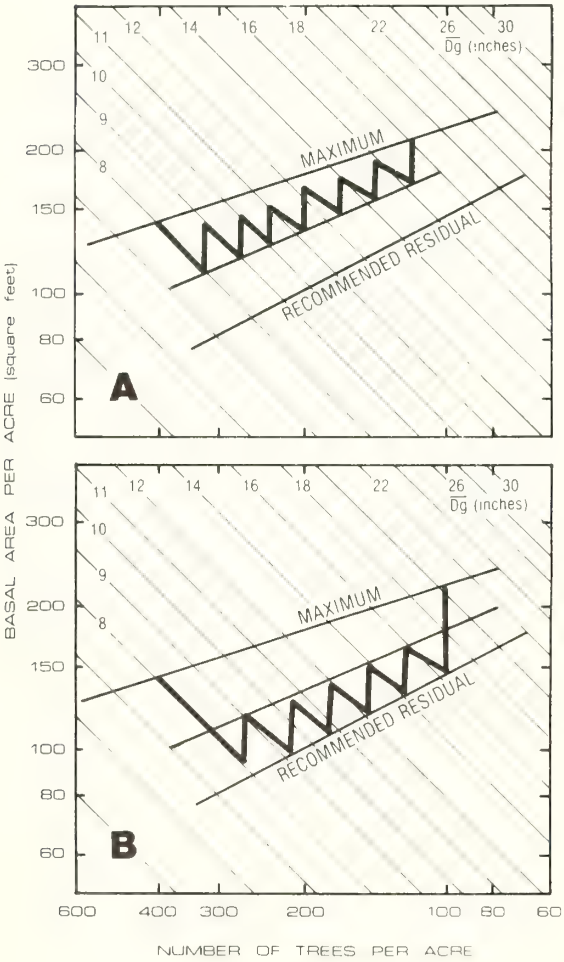

Figure 17.--Maintaining residual stocking level by frequent thinnings: A, At higher average level; B, at lower average level.

Type of Thinning
(Selection of Leave Trees)

Type of thinning is defined by the d/D ratio, which is $\overline{Dg}$ of cut trees (d) relative to $\overline{Dg}$ of merchantable trees before thinning (D). A reasonable trend over time can be established by relating d/D ratio to $\overline{Dg}$ of merchantable trees (D) and the *minimum* merchantable d.b.h. (dm) (fig. 18). We suggest that d/D at the first possible thinning should be between 1.0 and 0.9.[6] When dm is 0.4 D or less, d/D should be about 0.8.

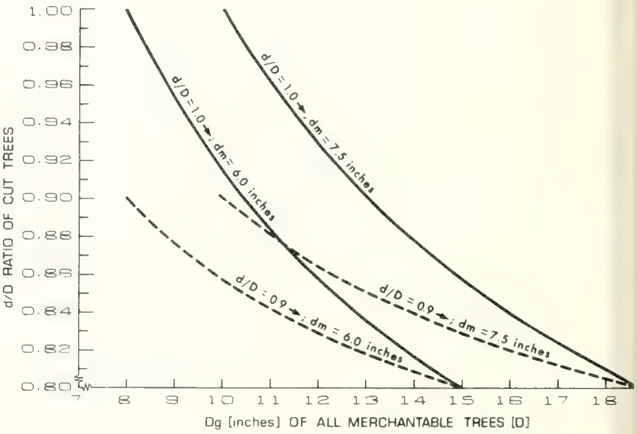

Figure 18.--Regimes of d/D ratio relative to mimimum merchantable d.b.h. (dm) and current $\overline{Dg}$ of merchantable trees (D).

When thinning is done at the "first possible" age, most merchantable trees will be capable of responding to release. Therefore, cut trees can be proportionately distributed across the range in merchantable size (d/D = 1.0). If largest trees are not cut, d/D may drop to about 0.9. On the other hand, the smaller merchantable trees could be left to grow; it is more important to properly space desirable large trees than to remove these smaller trees. Leaving these smaller trees would push d/D back toward 1.0. In young stands, there are opportunities to remove rough dominants; therefore, d/D on good sites (younger) could be a little greater than on poor sites (older).

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[6] It has not been uncommon for d/D to exceed 1.0 at first thinning on experimental plots.

When first thinning is delayed, merchantable trees will include suppressed trees, not capable of responding to release. Also, neighbors of large trees will be less able to respond to release. Therefore, the size distribution of cut trees should be skewed toward the smaller trees. Likewise, successive thinnings will have lower d/D ratios because thinning will generally include increasing proportions of lower crown classes. The minimum possible d/D ratio for a given percent cut is determined by stand structure; for example, removal of one-third of the basal area by cutting the *smallest* trees in an average natural stand would result in a d/D ratio of about 0.8.

Results of Thinning

In the following discussion of effects of thinning, as estimated by DFIT, on number and size of trees harvested and on volume production, we emphasize results applicable to *selected thinning regimes* and give detailed results pertinent thereto. We include supplementary discussions of some effects of alternate regimes. All results obtained from DFIT appear to be compatible with what we have observed on experimental plots.

Characteristics of the selected regimes are:

1. Precommercial thinning, if done, is done at age 10, 11, 12, 13, and 15 years on sites I through V, respectively.
2. *Minimum* merchantable d.b.h. is 6.0 inches (15.2 cm).
3. Stands are clearcut at age 85, 90, 95, 100, and 105 years on sites I through V, respectively.
4. Commercial thinning:
    a. Is begun at the first possible age; i.e., when merchantable portion of stand reaches MAXIMUM stocking level (fig. 13).
    b. Terminates at an age compatible with final-harvest age, so that merchantable portion of stand will be at approximately MAXIMUM stocking level at time of final harvest.
    c. Is done at the longest intervals compatible with other elements of the regime (table 1).
    d. Reduces merchantable portion of the stand, after each thinning, to the RECOMMENDED RESIDUAL stocking level or two-thirds of its basal area before thinning, whichever is greater.
    e. Follows the d/D ratio regime in figure 18 in which d/D ratio is 1.0 at the first thinning.

NUMBER AND SIZE OF TREES

Relation Between Number and Size

The relation between number and $\overline{Dg}$, together with how it is affected by thinning, is illustrated in figure 19. This particular example is for a site I stand. The example, however, applies to all sites; only the ages and the number of intervals would vary appreciably. This stand has been thinned five times, beginning at age 25, and carried to a rotation age of 85 years. Number and $\overline{Dg}$ of merchantable trees, at time of each thinning, are shown for both the thinned and unthinned stands. Also shown are the approximate cumulated stand curves (see fig. 4). Note that at the end of each period, $\overline{Dg}$ in the thinned stand is greater than that of *all* merchantable trees in the unthinned stand. At the ends of the first two intervals (ages 32 and 40), however, trees in the thinned stand are *smaller* than the *same number of largest trees* in the unthinned stand. At the end of the third interval, equal numbers of the largest trees are nearly the same size in the two stands. Thereafter, equal numbers of the largest trees are a little larger in the thinned stand than in the unthinned stand.

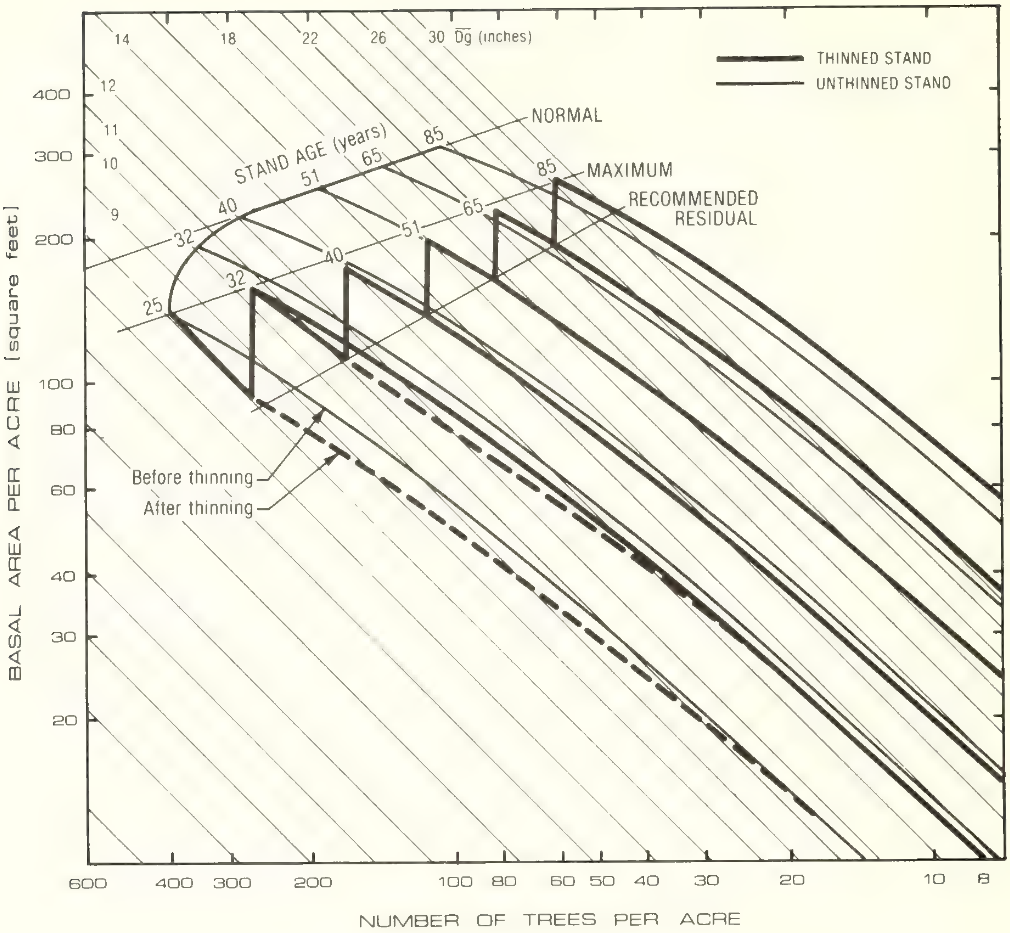

Figure 19.--Relative development of thinned and unthinned stands, by number and size of trees at specified ages.

Number of Trees

The number of trees which attain a specified minimum d.b.h. in average natural stands is assumed independent of site index (fig. 5B). In stands precommercially thinned to the desired number of trees, the number reaching a specified minimum d.b.h. will be the same as for natural stands. If we begin commercial thinning at the first possible age, all these merchantable trees will be harvested.

Number of Trees at Final Harvest

The part of this total number of trees which will be carried to final harvest varies with site quality, rotation age, and stand treatment regime. For our selected thinning regimes, number at final harvest ranges from 13 to 45 percent of the total initial number of merchantable trees (table 2). This relative number at final harvest increases with decreasing site quality and is less for stands that were precommercially thinned than for those that were not. Relative to unthinned stands of the same site and age, thinned stands have about 50 to 75 percent as many merchantable trees to be cut at final harvest. The smallest relative number is in good site, precommercially thinned stands, and the greatest is in poor site stands that were not precommercially thinned.

Table 2--*Number (N), average d.b.h. ($\overline{Dg}$), and basal area per acre (G) of merchantable trees 6 inches and larger in d.b.h. at final harvest of thinned stands, and their relationship to total yield of thinned stands and to live stand at final harvest of unthinned stands*

Site	Age	Treatment[1]	Current thinned stand			Percent of total yield of thinned stand		Relative to unthinned stand		
			N	$\overline{Dg}$	G	N	G	N	$\overline{Dg}$	G
	Years			Inches	Square feet	Percent				
I	85	CT alone	60	28.2	263	15	56	56	122	85
		PCT + CT	53	31.0	277	13	55	50	134	89
II	90	CT alone	78	23.8	240	19	58	60	118	83
		PCT + CT	66	26.8	256	16	56	50	133	88
III	95	CT alone	107	19.3	216	27	61	64	114	82
		PCT + CT	84	22.6	234	21	58	50	132	88
IV	100	CT alone	169	14.4	191	42	66	74	105	81
		PCT + CT	117	18.1	210	29	62	51	132	89
V	105	PCT + CT	180	13.5	178	45	67	54	130	90

Metric conversion: N per acre X 2.471 = N per ha; $\overline{Dg}$ in inches X 2.54 = $\overline{Dg}$ in centimeters; G in feet^2 per acre X 0.2296 = G in m^2 per ha.

[1] CT is commercial thinning; PCT is precommercial thinning.

Distribution of Trees Over Time

Merchantable trees not remaining for the final harvest have been removed in commercial thinnings (fig. 20). Many trees are removed at the first thinning, and progressively fewer at each successive thinning. Stands on good sites receive more thinnings than those on poor sites; stands that were precommercially thinned receive more thinnings than those which were not precommercially thinned. The number of merchantable trees in the unthinned stand is greater at each age.

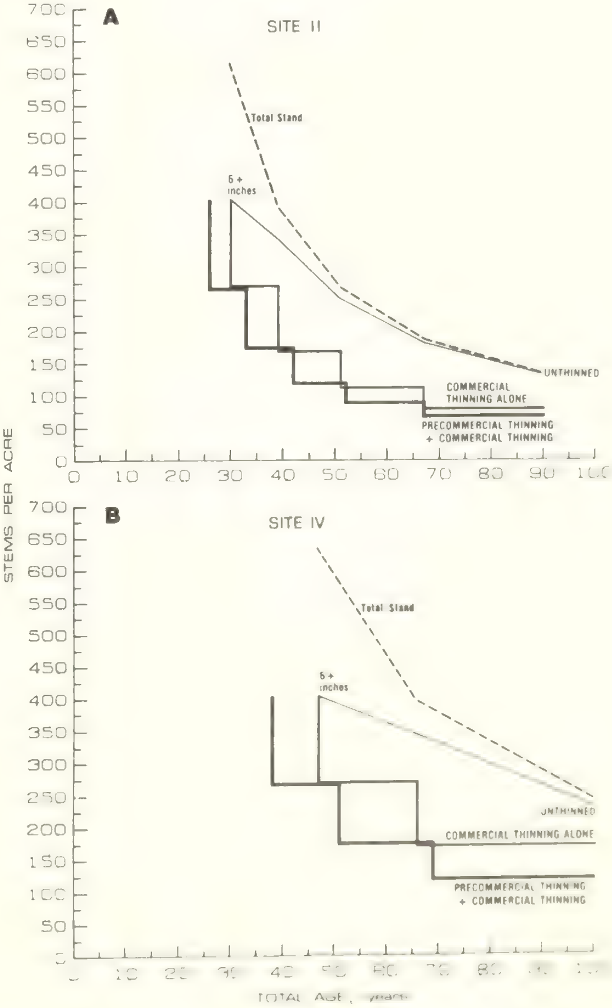

Figure 20.--Trends of number of trees over time: A, Site II; B, Site IV.

Diameter of Trees

Diameter at Final Harvest

As a corollary to number of trees, the $\overline{Dg}$ of trees at final harvest ranges from about 5 to 35 percent larger in thinned stands than the average of all merchantable trees remaining in unthinned stands (table 2). The greatest difference is in stands that have been precommercially thinned. When we compare $\overline{Dg}$ of residual trees in stands which were only commercially thinned with those of the *same number of largest trees* in natural stands, however, we find that they are similar (fig. 19). In *precommercially* thinned stands, the $\overline{Dg}$ of trees will generally be 10 to 15 percent larger than the $\overline{Dg}$ of the same number of largest trees in unthinned stands. Increased growth of residual trees is more or less offset by the removal of some larger than average trees in thinnings--trees which would otherwise be present at final harvest.

Trends Over Time

The increase in $\overline{Dg}$ over time reflects a combination of growth of surviving trees and loss of trees from the stand. Therefore, the trend over time in thinned stands is quite different from that in unthinned stands (fig. 21). In an unthinned stand, the increase in $\overline{Dg}$ of merchantable trees progresses smoothly over time--on a steadily declining number of trees; the increase in $\overline{Dg}$ is greater than the d.b.h. growth of surviving trees. In the thinned stand, there is an abrupt increase in $\overline{Dg}$ each time the stand is thinned (if d/D is less than 1.0); the increase between thinnings is the actual growth of survivors.

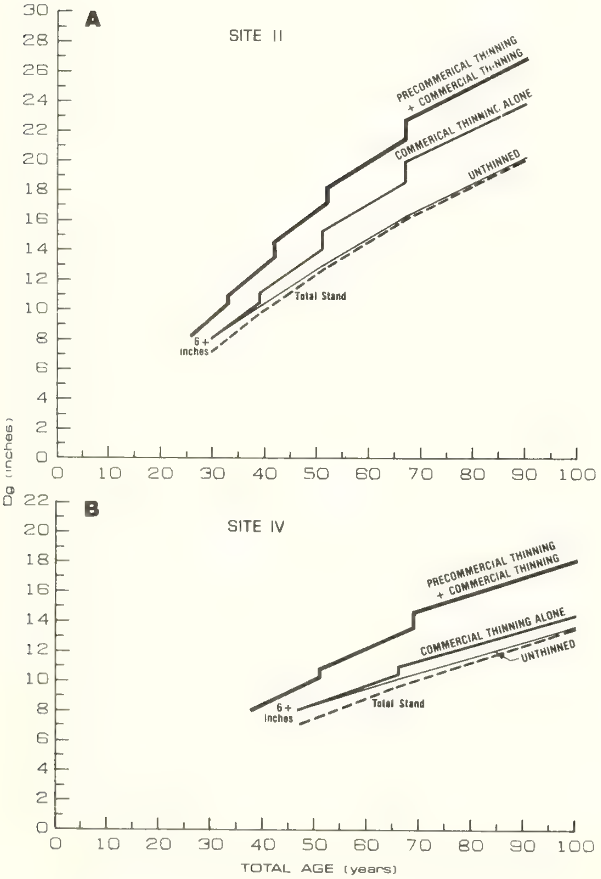

Figure 21.--Trends of Dg over time: A, Site II; B, site IV.

On good sites the gain in $\overline{Dg}$ because of commercial thinning is greater than the additional gain from precommercial thinning. On poor sites, the reverse is true. The d.b.h. growth rate with commercial thinning alone is very close to the rate of increase in $\overline{Dg}$ of merchantable trees in the natural stand;--a little better on good sites. Diameter growth rate with precommercial thinning is always a little better than with commercial thinning alone.

Effects of Alternate Thinning Regimes

Minimum Merchantable D.b.h.

The larger the minimum merchantable d.b.h. (dm) is, the fewer and the larger are the trees harvested (table 3). The effect on the final harvest is fairly minor. With only commercial thinning, a larger dm tends to result in *slightly* more trees and smaller trees at final harvest; in precommercially thinned stands, the reverse is true. The major effect is on trees removed in thinnings. With a larger dm, a much smaller number of trees is removed; as a result, the $\overline{Dg}$ of both the trees harvested in thinnings and all trees harvested is larger.

Delayed First Thinning

The effect of delaying the first commercial thinning is similar to the foregoing. Fewer live trees will be available for harvest in thinnings; however, part of this loss can be offset by salvage of recent merchantable mortality (table 4). Growth rates of merchantable trees will be reduced somewhat during this delay period;

Table 3--*Number (N) and average d.b.h. ($\overline{Dg}$) of trees harvested in commercial thinnings and at final harvest, by site, treatment, and minimum merchantable d.b.h. (dm)*

Treatment and dm	Site I		Site II		Site III		Site IV		Site V	
	N	$\overline{Dg}$	N	$\overline{Dg}$	N	$\overline{Dg}$	N	$\overline{Dg}$	N	$\overline{Dg}$
		Inches		Inches		Inches		Inches		Inches
ONLY COMMERCIAL THINNING										
6.0+ inches:										
Thinnings	343	10.6	327	10.0	295	9.3	235	8.6	--	--
Final harvest	60	28.2	78	23.8	107	19.3	169	14.4	--	--
Total number of trees	403	14.6	405	13.8	402	12.8	404	11.4	--	--
7.5+ inches:										
Thinnings	225	12.1	207	11.5	176	10.9	116	10.1	--	--
Final harvest	64	27.3	82	23.0	113	18.5	172	14.2	--	--
Total number of trees	289	16.7	289	15.6	289	14.3	288	12.7	--	--
PRECOMMERCIAL THINNING + COMMERCIAL THINNING										
6.0+ inches:										
Thinnings	349	10.9	336	10.4	318	9.8	284	9.2	222	8.5
Final harvest	53	31.0	66	26.8	84	22.6	117	18.1	180	13.5
Total number of trees	402	15.2	402	14.4	402	13.5	401	12.5	402	11.0
7.5+ inches:										
Thinnings	235	12.8	222	12.1	205	11.5	176	10.9	126	10.2
Final harvest	52	31.1	65	27.1	82	22.9	111	18.7	161	14.4
Total number of trees	287	17.6	287	16.7	287	15.7	287	14.4	287	12.7

Metric conversion: N per acre X 2.471 = N per ha.
$\overline{Dg}$ in inches X 2.54 = $\overline{Dg}$ in centimeters.

Table 4--*Number (N) and average d.b.h. ($\overline{Dg}$) of merchantable live trees remaining if thinning is delayed, and corresponding periodic merchantable mortality, when minimum merchantable d.b.h. is 6.0 inches*

Site	First possible age for thinning	Number of years delayed							
		0		10		20		30	
		N	$\overline{Dg}$	N	$\overline{Dg}$	N	$\overline{Dg}$	N	$\overline{Dg}$
	Years		Inches		Inches		Inches		Inches
LIVE TREES									
I	25	403	8.0	312	11.0	227	13.8	176	16.4
II	30	405	8.1	333	10.4	256	12.7	206	14.8
III	36	402	8.0	362	9.7	297	11.4	248	13.0
IV	47	403	8.1	382	9.2	336	10.4	--	--
V	68	403	8.0	--	--	--	--	--	--
DEAD TREES									
I	25	0	--	91	6.8	85	8.3	50	10.1
II	30	0	--	72	6.7	76	7.9	50	9.3
III	36	0	--	40	6.8	65	7.4	49	8.4
IV	47	0	--	21	7.2	46	7.2	--	--
V	68	0	--	--	--	--	--	--	--

Metric conversion: N per acre X 2.471 = N per hectare.
$\overline{Dg}$ in inches X 2.54 = $\overline{Dg}$ in centimeters.

furthermore, they will continue to be lower after thinning than if the stand had been thinned earlier--the longer the delay, the greater the loss.

Frequency and Severity of Thinning

Reducing the average growing stock level leads to fewer and larger trees at final harvest; increasing the average level leads to more and smaller trees at final harvest. Relating this to the natural stand curve illustrates how $\overline{Dg}$ at final harvest of these thinned stands compares with that of the *same number of largest trees in* the unthinned stand (fig. 22A). $\overline{Dg}$ of trees removed in thinnings is greatest in the stand maintained at a high average level and least in the stand maintained at a low average level, but difference are small.

Type of Thinning

The higher the d/D ratio is at the first possible commercial thinning, the greater the number of trees and the smaller the average d.b.h. of trees remaining at any time (fig. 22B). The relative difference decreases with each successive thinning. Thus, differences, both at final harvest and averaged over the rotation, tend to decrease with increasing site quality and to be less in stands that are precommercially thinned than in those that are not.

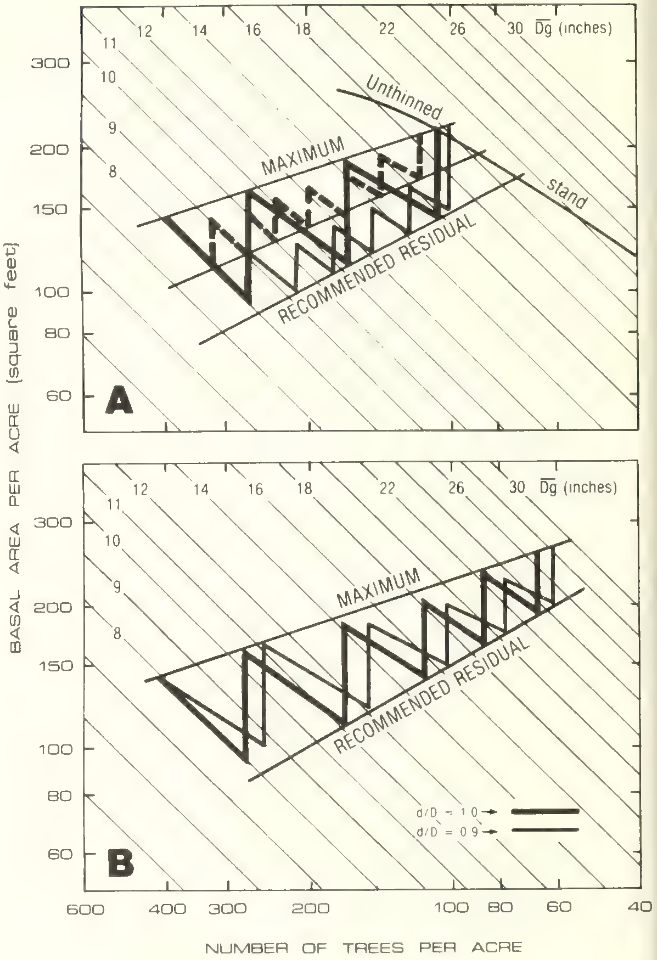

Figure 22.--Effects of alternate thinning regimes on number and size of trees: A, Alternate stocking and thinning interval; B, alternate type of thinning (d/D regime).

VOLUME YIELD

Gains in Total Merchantable Production

Gains in merchantable production depend on merchantability standards, as well as on the age at which comparisons are made. Therefore, to illustrate the basic effects of thinning, we first examine relationships in terms of cubic volume of total stem (CVTS). To provide perspective regarding the effect of age, we compare *maximum* mean annual increments (m.a.i.), regardless of ages at which this culmination occurs; we then illustrate the effects of making comparisons at other ages. We then examine gains at our selected rotation ages by various measures of merchantable production.

Culmination of m.a.i.

When does m.a.i. culminate? Any practice or merchantability standard that increases merchantable production early in the rotation more than toward the end will reduce the age at which culmination occurs.

Conversely, anything that increases merchantable production later rather than earlier in the rotation will increase the age of culmination.

Thus, whereas gross m.a.i. in terms of total stand CVTS culminates at about age 63 on all sites, merchantable m.a.i. culminates later on progressively poorer sites--ranging from about 65 years on site I to 105 years on site V. Thinnings reduce the ages at which merchantable m.a.i. culminates; thus, culmination ages in stands receiving early precommercial thinning range from about 65 to 85 years on sites I through V. Board-foot m.a.i. culminates at later ages than cubic-foot m.a.i.

Cubic Volume of Total Stem

One should first have a clear understanding of the relationship of merchantable yield[7] to total yield in natural stands; then one should compare *merchantable* yields with and without thinning. At ages of maximum m.a.i., total gross yield in unthinned stands is about 38 percent greater than net yield. The portion of this gross yield contained in merchantable trees--6 inches (15 cm) d.b.h. and larger--is about 8 to 33 percent less than total gross yield on sites I through V (fig. 23A).

Merchantable gross yield of stands receiving only commercial thinning is less than that of unthinned stands (fig. 23B). This is a result of the reduced growth per acre which occurs between first thinning and final harvest. This loss is, generally, considerably less than the merchantable volume otherwise lost to mortality, however. Yield of precommercially thinned stands is also less than *total* gross yield of unthinned stands, but not as much so. All precommercially thinned stands receive a lasting benefit from concentrating growth onto merchantable trees.

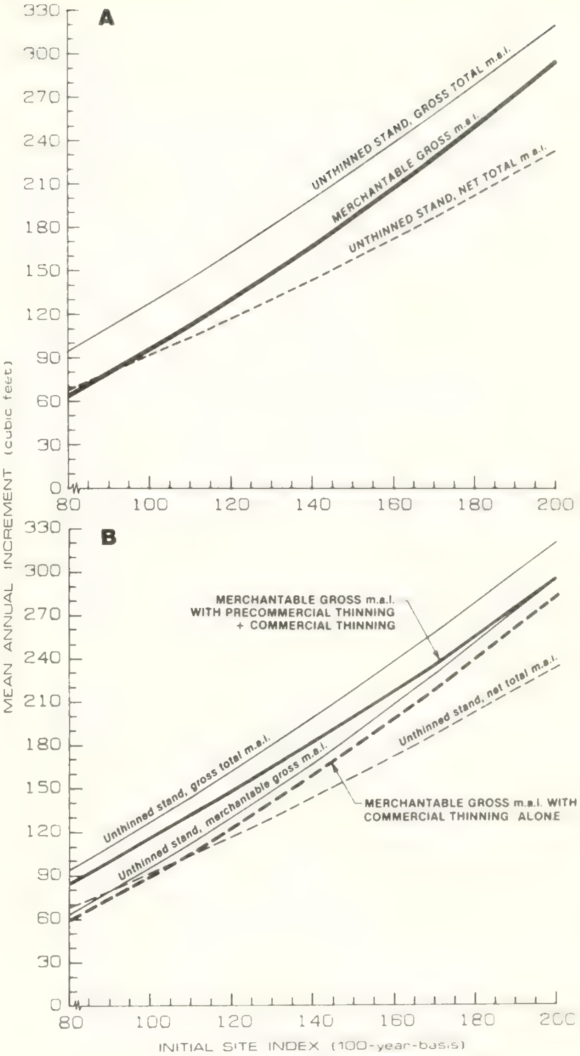

Figure 23.--Mean annual increment of cubic volume of total stem (CVTS) at time it culminates, when minimum merchantable d.b.h. is 6.0 inches: A, Merchantable m.a.i. relative to total m.a.i. in unthinned stands; B, merchantable m.a.i. with commercial thinning relative to that without thinning.

The additional benefit associated with improved height growth increases with decreasing site quality.

At ages other than culmination of m.a.i., relative yields are somewhat different from those discussed above (fig. 24). At ages prior to culmination, differences in m.a.i. between precommercially thinned stands and those receiving only commercial thinning are a little greater; at ages later than culmination, differences in m.a.i. are a little less. Prior to culmination, differences in merchantable yield between unthinned stands and commercially thinned stands are less; after culmination, differences are greater. The rotation ages we have chosen for our examples are about 20 years beyond culmination of merchantable CVTS in precommercially thinned stands, but substantially earlier than culmination of m.a.i. in terms of board-foot volume. For the remainder of this section, all comparisons are based on these chosen rotation ages.

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[7] In terms of CVTS, merchantable yield refers to CVTS of merchantable size trees.

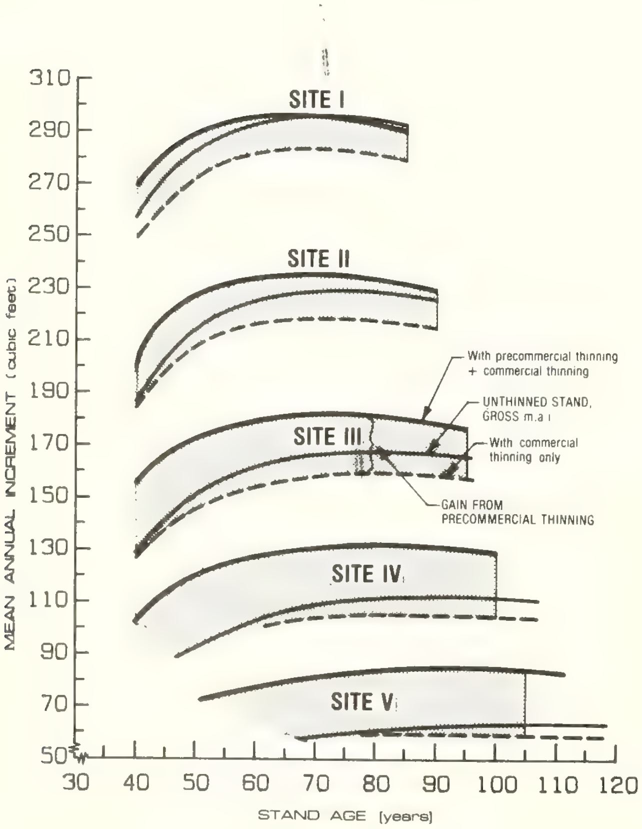

Figure 24.--Mean annual increment of merchantable cubic volume of total stem (CVTS) at ages before and after culmination, when minimum merchantable d.b.h. is 6.0 inches.

Gains by Different Measures of Production

Mean annual increments by five measures of merchantable production are shown in table 5 for the selected regimes. This table is intended to provide the reader with some specific estimates of yield, as well as providing background for subsequent discussion.

Table 5--*Mean annual increment at specified rotation ages, by site, treatment, and various measures of production; trees 6.0 inches and larger in d.b.h.*

Site, age, and treatment	Measure of production[1] G	CVTS	CV4	IV5	SV6
	Square feet	- - Cubic	feet - -	- - Board	feet - -
Site I, 85 years:					
Unthinned	3.65	215.8	212.2	1546.1	1397.6
Unthinned plus salvable[2]	3.87	227.8	224.0	1627.1	1466.1
Commercial thinning alone	5.55	278.4	270.1	1863.5	1636.5
Precommercial thinning + commercial thinning	5.92	289.3	280.7	1947.7	1728.6
Site II, 90 years:					
Unthinned	3.22	170.4	167.3	1175.9	1045.8
Unthinned plus salvable[2]	3.40	179.2	175.9	1231.7	1091.6
Commercial thinning alone	4.64	214.2	207.1	1376.4	1182.4
Precommercial thinning + commercial thinning	5.03	228.9	221.5	1490.4	1300.2
Site III, 95 years:					
Unthinned	2.79	129.0	125.7	832.0	714.5
Unthinned plus salvable[2]	2.94	135.2	131.6	867.2	741.7
Commercial thinning alone	3.75	155.8	149.5	939.3	778.4
Precommercial thinning + commercial thinning	4.21	176.5	169.9	1095.3	931.8
Site IV, 100 years:					
Unthinned	2.36	91.6	87.9	528.2	427.4
Unthinned plus salvable[2]	2.47	95.6	91.6	547.4	440.4
Commercial thinning alone	2.87	103.8	98.1	565.8	436.9
Precommercial thinning + commercial thinning	3.41	128.7	122.7	744.6	607.9
Site V, 105 years:					
Unthinned	1.88	57.7	53.6	276.8	189.4
Unthinned plus salvable[2]	1.95	59.6	55.3	284.1	192.9
Precommercial thinning + commercial thinning	2.52	82.4	77.2	426.9	320.6

Metric conversion: G in square feet per acre X 0.2296 = G in square meters per hectare.
CV in cubic feet per acre X 0.0700 = CV in cubic meters per hectare.

[1] G = basal area; CVTS = cubic volume of total stem; CV4 = cubic volume to a 4-inch (10-cm) top d.i.b.; IV5 = International board-foot volume to a 5-inch (13-cm) top, 1/4-inch kerf; SV6 = Scribner board-foot volume to a 6-inch (15-cm) top (Scribner volume is the formula version applied to 16-foot logs). CV4, IV5, and SV6 exclude volume in the stump.

[2] For this comparison, all merchantable mortality occurring within 10 years of final harvest is assumed to be salvable at final harvest.

To provide realistic estimates of gains from thinning, we have added estimates of salvable mortality to the live volumes harvested from unthinned stands. This is the estimated merchantable mortality which occurred during the 10-year period prior to harvest. The amount that this salvage adds to total usable production decreases with decreasing site quality and with measures of merchantable volume which exclude progressively more of the total volume.

The corresponding percentage and absolute gains in CV4 yield are illustrated in figure 25. Gains from only commercial thinning are greatest on good sites, whereas the *additional* gains from precommercial thinning are greater on poorer-than-average sites. With our assumptions, the maximum increase in CV4 m.a.i. due to precommercial thinning occurs at about site index 100. Relative gains by other measures of volume production are shown in table 6.

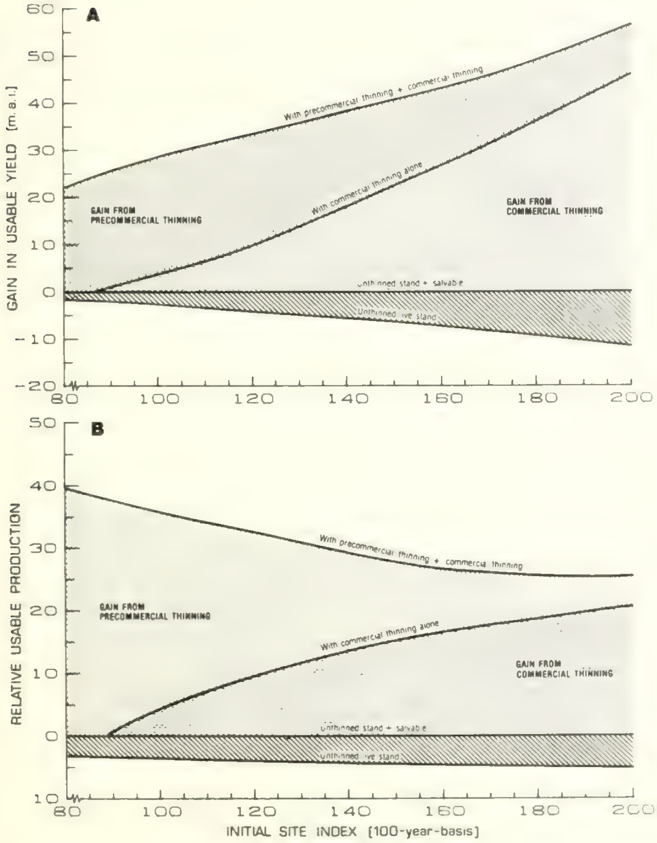

Figure 25.--Gains in merchantable cubic volume (CV4) due to thinning: A, Absolute gains; B, percentage gains.

Table 6--*Gains in mean annual increment to specified rotation ages, by site and various measures of production; trees 1.6 inches and larger in d.b.h.*[1]

Site, age, and treatment	Measure of production[2]				
	G	CVTS	CV4	IV5	SV6
	ABSOLUTE GAIN				
	Square feet	- - Cubic - -	feet	- - Board - -	feet
Site I, 85 years:					
Commercial thinning alone	1.68	50.6	46.1	236	170
Precommercial thinning + commercial thinning	2.05	61.5	56.7	321	262
Difference [3]	.37	10.9	10.6	85	92
Site II, 90 years:					
Commercial thinning alone	1.24	35.0	31.2	145	91
Precommercial thinning + commercial thinning	1.63	49.7	45.6	259	209
Difference [3]	.39	14.7	14.4	114	118
Site III, 95 years:					
Commercial thinning alone	.81	20.6	17.9	72	37
Precommercial thinning + commercial thinning	1.27	41.3	38.3	228	190
Difference [3]	.46	20.7	20.4	156	153
Site IV, 100 years:					
Commercial thinning alone	.40	8.2	6.5	18	- 3
Precommercial thinning + commercial thinning	.94	33.1	31.1	197	168
Difference [3]	.54	24.9	24.6	179	171
Site V, 105 years:					
Commercial thinning alone	--	--	--	--	--
Precommercial thinning + commercial thinning	.57	22.8	21.9	143	128
Difference [3]	.57	22.8	21.9	143	128
	PERCENTAGE GAIN				
	- - - - - - - Percent - - - - - - -				
Site I, 85 years:					
Commercial thinning alone	43	22	21	15	12
Precommercial thinning + commercial thinning	53	27	25	20	18
Difference [3]	10	5	4	5	6
Site II, 90 years:					
Commercial thinning alone	36	20	18	12	8
Precommercial thinning + commercial thinning	48	27	26	21	19
Difference [3]	11	7	7	8	10
Site III, 95 years:					
Commercial thinning alone	28	15	14	8	5
Precommercial thinning + commercial thinning	43	31	29	26	26
Difference [3]	16	15	14	17	21
Site IV, 100 years:					
Commercial thinning alone	16	9	7	3	- 1
Precommercial thinning + commercial thinning	38	35	34	36	38
Difference [3]	22	26	27	32	39
Site V, 105 years:					
Commercial thinning alone	--	--	--	--	--
Precommercial thinning + commercial thinning	29	38	40	50	66
Difference [3]	29	38	40	50	66

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[1] Gains are relative to unthinned plus salvable (from table 5).

[2] G = basal area; CVTS = cubic volume of total stem; CV4 = cubic volume to a 4-inch (10-cm) top d.i.b.; IV5 = International board-foot volume to a 5-inch (13-cm) top, 1/4-inch kerf; SV6 = Scribner board-foot volume to a 6-inch (15-cm) top (Scribner volume is the formula version applied to 16-foot logs). CV4, IV5, and SV6 exclude volume in the stump.

[3] Difference between precommercial thinning + commercial thinning and commercial alone is gain due to precommercial thinning.

Note that relative gains from commercial thinning decrease as less of the total volume in merchantable trees is deemed usable; that is, greatest for CVTS and least for SV6. The trend for additional gains from precommercial thinning is the reverse; least for CVTS and greatest for SV6. Relative gains on different sites also vary with the measure of production; however, by all measures, the absolute gain from precommercial thinning is greatest on site IV.

Distribution of Yields Over Time

The accumulation of total yield over time and the distribution of this yield among thinnings and final harvest, for the selected regimes, are illustrated in figures 26-28 for sites II and IV in terms of basal area, CV4, and IV5. The total-yield curves in these figures supplement the foregoing discussion and further indicate relative gains in yield with shorter rotations. The following discussion will focus on the residual stand--before and after each cutting. Attention is directed first to the volume remaining for the final harvest and then to volume removed in thinnings.

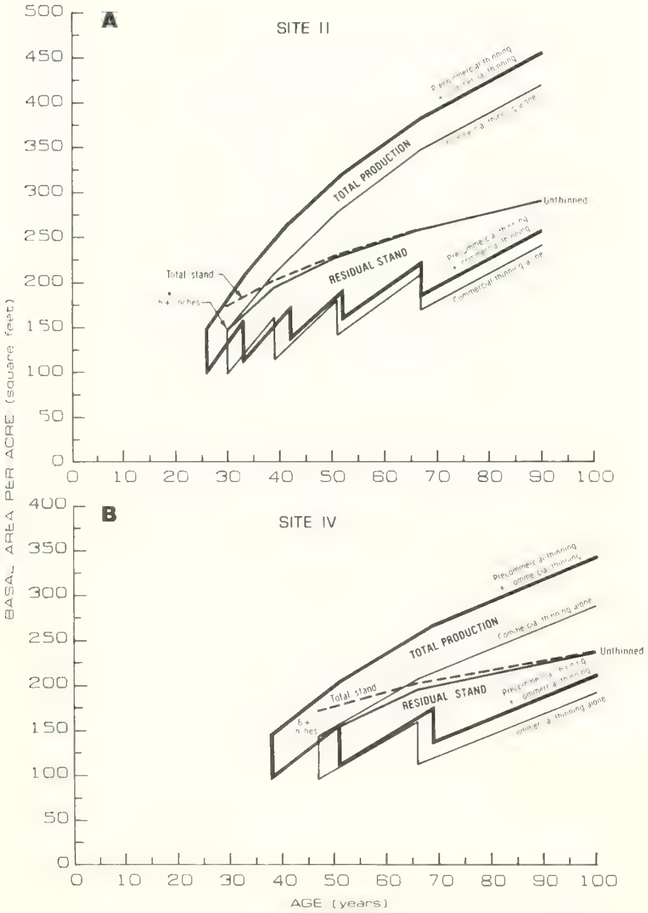

Figure 26.--Trends of basal area production over time: A, Site II; B, Site IV.

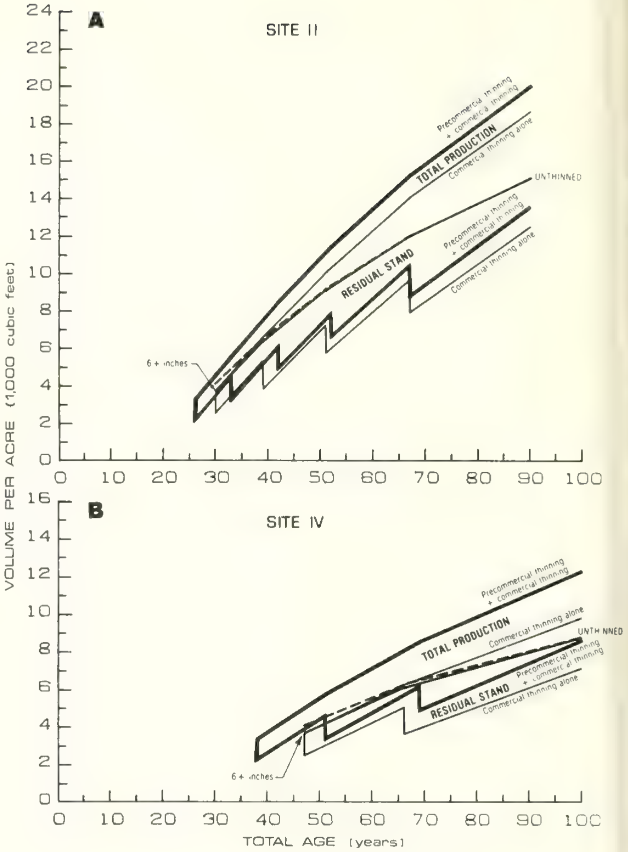

Figure 27.--Trends of cubic volume (CV4) production over time: A, Site II; B, site IV.

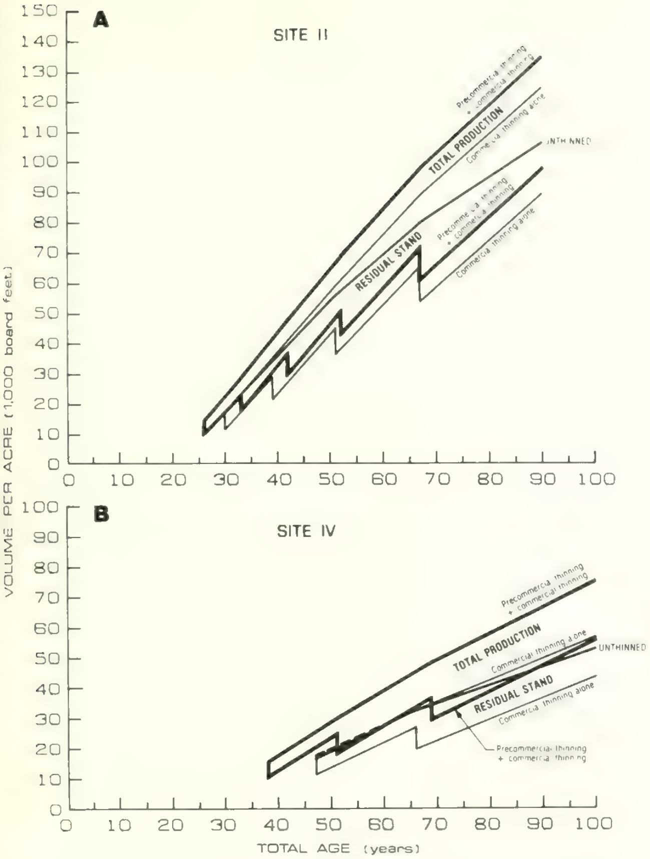

Figure 28.--Trends of board-foot volume (IV5) production over time: A, Site II; B, site IV.

Volume at Final Harvest

The cubic volume removed at final harvest averages about 70 percent of the total volume harvested from the stand (table 7); the remainder is harvested in thinnings. The proportion of volume at final harvest varies somewhat with timespan and growth rate and with the measure of merchantable volume. Thus, it is a little greater on poor sites than on good sites and is greater in terms of board-foot volume than in terms of total cubic-foot volume. (If below MAXIMUM, volume at final harvest would be proportionately less.)

The volume available at final harvest of thinned stands is generally less than that of corresponding unthinned stands (figs. 26-28, table 8). For stands receiving only *commercial thinning*, this volume at final harvest is about 85 percent of the volume of live merchantable trees in natural stands of the same site and age. This ratio increases slightly with increasing site index and is slightly greater for board-foot volume than for cubic-foot volume. For stands that were *precommercially thinned*, this ratio of volume at final harvest to final volume of comparable natural stands increases with decreasing site quality and, especially on poor quality sites, is substantially greater for board-foot volume than for cubic-foot volume. On poor sites, board-foot volume at final harvest (as well as total production) is greater than that in comparable unthinned stands.

Volume Removed in Thinnings

Volume removed in thinnings averages about 30 percent of the total merchantable cubic volume produced; a little more on good sites, which require more frequent thinning, than on poor sites. Proportionately less of the total production of board foot volume is removed in thinnings because much of the volume in thinnings is in relatively small trees which contribute proportionately more to total volume than to board-foot volume.

With our selected regimes, the first commercial thinning removes an average of about 1,360 cubic feet per acre (102 m^3 per ha) from stands that were not precommercially thinned and about 1,210 cubic feet per acre (91 m^3 per ha) from those that were. The 11-percent lower volume in precommercially thinned stands results from trees being younger--and thus shorter--when they reach the specified d.b.h. Similar differences between stands that were precommercially thinned and those that were not persist throughout all subsequent thinnings. The amount of volume removed tends to increase with each successive thinning, at a fairly slow rate for cubic volume but more rapidly for board-foot volume (figs. 27 and 28).

Table 7--*Final harvest in thinned stands as percent of their total production to specified rotation ages, by site, treatment, and various measures of production; trees 6.0 inches and larger in d.b.h.*

Site, age, and treatment	Measure of production[1/]					
	N	G	CVTS	CV4	IV5	SV6
			Percent			
Site I, 85 years:						
Commercial thinning alone	15	56	66	67	71	74
Precommercial thinning + commercial thinning	13	55	66	67	71	75
Site II, 90 years:						
Commercial thinning alone	19	58	66	67	72	76
Precommercial thinning + commercial thinning	16	56	67	68	72	76
Site III, 95 years:						
Commercial thinning alone	27	61	68	69	73	76
Precommercial thinning + commercial thinning	21	58	67	68	73	77
Site IV, 100 years:						
Commercial thinning alone	42	66	72	72	77	81
Precommercial thinning + commercial thinning	29	62	69	70	74	80
Site V, 105 years:						
Precommercial thinning + commercial thinning	45	67	72	73	77	82
Average	--	62	69	70	74	78

[1/] N = number of trees; G = basal area; CVTS = cubic volume of total stem; CV4 = cubic volume to a 4-inch (10-cm) top d.i.b.; IV5 = International board-foot volume to a 5-inch (13-cm) top, 1/4-inch kerf; SV6 = Scribner board-foot volume to a 6-inch (15-cm) top (Scribner volume is the formula version applied to 16-foot logs). CV4, IV5, and SV6 exclude volume in the stump.

Table 8--*Final harvest in thinned stands relative to harvest of live trees in unthinned stands at specified rotation ages, by site, treatment, and various measures of production; trees 6.0 inches and larger in d.b.h.*[1/]

Site, age, and treatment	Measure of production[2/]						
	N	$\overline{Dg}$	G	CVTS	CV4	IV5	SV6
				Percent			
Site I, 85 years:							
Commercial thinning alone	56	122	85	85	85	86	87
Precommercial thinning + commercial thinning	50	134	89	89	89	90	93
Precommercial thinning gain[3/]	--	10	5	5	5	5	7
Site II, 90 years:							
Commercial thinning alone	60	118	83	83	83	84	86
Precommercial thinning + commercial thinning	50	133	88	90	90	92	94
Precommercial thinning gain	--	12	6	8	8	10	9
Site III, 95 years:							
Commercial thinning alone	64	114	82	82	82	83	82
Precommercial thinning + commercial thinning	50	132	88	92	92	96	100
Precommercial thinning gain	--	16	7	12	12	16	22
Site IV, 100 years:							
Commercial thinning alone	74	105	81	81	81	82	83
Precommercial thinning + commercial thinning	51	132	89	97	98	105	113
Precommercial thinning gain	--	26	10	20	21	28	37
Site V, 105 years:							
Precommercial thinning + commercial thinning	54	130	90	103	105	118	138

[1/] Expressed as percent of volume in live trees in an unthinned stand of the same initial site index. Salvage of mortality in unthinned stands would reduce these percentages a little.

[2/] N = number of trees; $\overline{Dg}$ = average d.b.h.; G = basal area; CVTS = cubic volume of total stem; CV4 = cubic volume to a 4-inch (10-cm) top d.i.b.; IV5 = International board-foot volume to a 5-inch (13-cm) top, 1/4-inch kerf; SV6 = Scribner board-foot volume to a 6-inch (15-cm) top (Scribner volume is the formula version applied to 16-foot logs). CV4, IV5, and SV6 exclude volume in the stump.

[3/] Precommercial thinning gain is [(precommercial thinning + commercial thinning) - commercial thinning] ÷ commercial thinning.

Effects of Alternate Thinning Regimes

Minimum Merchantable D.b.h.

The effect of minimum merchantable d.b.h. (dm) on total merchantable production is greater for stands receiving only commercial thinning than for precommercially thinned stands (table 9) because the latter were thinned to stand densities commensurate with this minimum d.b.h. For stands receiving *only commercial thinning*, merchantable yields with a dm of 7.5 inches (19 cm) are less than those with a dm of 6.0 inches (15 cm) by all measures of volume. Relative reductions in yield are greatest on site IV and progressively less with increasing site index. Yield reductions are less when increasing proportions of total volume are nonmerchantable; thus, less for board-foot volume than for cubic volume. For *precommercially thinned* stands, differences associated with dm--and, thus, with spacing of trees--are minor. As

Table 9--*Effect of minimum merchantable d.b.h. (dm) on merchantable yield to specified rotation ages, by site, treatment, and various measures of volume; when dm is 7.5 inches versus 6.0 inches*

Treatment, site, and age	Measure of volume[1]			
	CVTS	CV4	IV5	SV6
	ABSOLUTE DIFFERENCE[2]			
	- - Cubic feet - -		- - Board feet - -	
Commercial thinning alone:				
Site I, 85 years	994	858	4,499	2,958
Site II, 90 years	990	850	4,132	2,450
Site III, 95 years	951	813	3,818	1,981
Site IV, 100 years	879	744	3,195	1,390
Precommercial thinning + commercial thinning:				
Site I, 85 years	299	198	[3] -19	-1,416
Site II, 90 years	323	220	81	-1,453
Site III, 95 years	324	218	-13	-1,563
Site IV, 100 years	305	199	-160	-1,724
Site V, 105 years	259	155	-297	-1,801
	PERCENTAGE DIFFERENCES			
		Percent		
Commercial thinning alone:				
Site I, 85 years	4.2	3.7	2.8	2.1
Site II, 90 years	5.1	4.6	3.3	2.3
Site III, 95 years	6.4	5.7	4.3	2.7
Site IV, 100 years	8.5	7.6	5.6	3.2
Precommercial thinning + commercial thinning:				
Site I, 85 years	1.2	.8	0	-1.0
Site II, 90 years	1.6	1.1	.1	-1.2
Site III, 95 years	1.9	1.4	0	-1.8
Site IV, 100 years	2.4	1.6	-.2	-2.8
Site V, 105 years	3.0	1.9	-.7	-5.3

[1] CVTS = cubic volume of total stem; CV4 = cubic volume to a 4-inch (10-cm) top d.i.b.; IV5 = International board-foot volume to a 5-inch (13-cm) top, 1/4-inch kerf; SV6 = Scribner board-foot volume to a 6-inch (15-cm) top (Scribner volume is the formula version applied to 16-foot logs). CV4, IV5, and SV6 exclude volume in the stump.

[2] Difference is yield when dm (minimum merchantable d.b.h.) = 6.0 inches minus yield when dm = 7.5 inches. Percent is this difference divided by the former.

[3] Negative difference means yields are greater when dm = 7.5 inches (i.e., with wider spacing).

with stands receiving only commercial thinning, reductions in cubic volume yield when dm is 7.5 inches (19 cm) instead of 6.0 inches (15 cm) increase with decreasing site index. In terms of Scribner volume (SV6), however, production is *greater* in the stand with fewer trees; the relative improvement increases with decreasing site quality.

Delayed First Thinning

The major loss caused by delayed commercial thinning is the volume in merchantable trees which die prior to thinning. This loss is partly offset by salvage of some of these dead trees when the first thinning is made. An additional, but smaller, loss is due to a greater reduction in growth per acre once the first thinning is made. The net effect of a short delay may be quite small, but progressively longer delay may result in substantial losses. This is illustrated for a site II stand in table 10. In this example, gains in merchantable CVTS due to commercial thinning

Table 10--*Effect on usable production (CVTS) of delaying commercial thinning in a site II natural stand when minimum merchantable d.b.h. is 6.0 inches*

Stand and item	Stand age (years)					Percent of potential gain
	30	39	51	67	90	
	- - - - - - Cubic feet - - - - - -					
Unthinned stand:						
Cumulated mortality	0	439	1,534	3,032	4,953	
Cumulated growth	0	3,093	6,822	11,093	16,088	
"Captured" mortality	0	--	--	--	792	
Thinned at age 30:						
Cumulated "captured" mortality	0	439	1,534	3,032	4,953	
Cumulated "lost" growth	0	193	426	693	1,006	
Net gain	0	--	--	--	3,947	
Adjusted net gain[1]	0	--	--	--	3,155	100
Thinned at age 39:						
Cumulated "captured" mortality	--	[2]390	1,485	2,983	4,904	
Cumulated "lost" growth	--	0	317	680	1,105	
Net gain	--	--	--	--	3,799	
Adjusted net gain[1]	--	--	--	--	3,007	95
Thinned at age 51:						
Cumulated "captured" mortality	--	--	890	2,388	4,309	
Cumulated "lost" growth	--	--	0	491	1,066	
Net gain	--	--	--	--	3,243	
Adjusted net gain[1]	--	--	--	--	2,451	78

[1] Adjusted net gain = difference between captured mortality and "lost" potential growth minus salvable mortality at final harvest in natural stands.

[2] Assumes that salvage at first commercial thinning = 80 percent of total 10-year merchantable mortality ÷ d/D ratio at first commercial thinning. d/D is the ratio of Dg of cut trees to Dg of all merchantable trees present before thinning. Thus,

d/D	Percent salvable
1.0	80
.9	89
.8	100

are 95 percent as great when thinning is delayed 9 years (to age 39) as if it were done at the first possible age (age 30). If the first thinning is delayed 21 years (to age 51), gains are only 78 percent as great as if it were done at age 30.

Frequency and Severity of Thinning

With our assumptions, differences in residual stocking level (within suggested limits) and/or frequency of thinning have no effect on total cubic volume production. Thus, other regimes alter only the distribution of harvested volume over time and among various sizes of trees. For the alternate regimes discussed previously under number and size of trees (fig. 22A), differences in total production by all measures of volume are negligible. Differences in volume at final harvest in the stand maintained at the low average stocking level is 4 to 7 percent greater than in the stand maintained at the high average stocking level. Correspondingly, stands with the greatest volume at time of final harvest have a little less volume removed in thinnings.

Type of Thinning

Likewise, type of thinning is assumed to have no effect on total cubic volume production, and it has only a slight effect on total production by other measures of volume. If the d/D ratio progresses from 0.9 to 0.8 rather than from 1.0 to 0.8 (fig. 22B), total production by all measures of volume remains virtually the same. The amount cut at each thinning is a little less--especially at the first two thinnings--so volume remaining at final harvest is a little greater. This difference in final harvest volume is, however, less than 3 percent.

Extrapolation to Other Stand Conditions

Structure and development of most natural stands differ from that of the average natural stand which we have described. Some stands are understocked and others overstocked, relative to the average. Some are very uniform and others extremely variable in composition. In some stands, the pattern of height growth relative to stand age is quite different from what we have assumed--so site index does not remain constant. We do not attempt to specifically estimate the effects of these variations, but in this section we briefly discuss their possible effects.

UNIFORMLY UNDERSTOCKED STANDS

An understocked stand is one in which average d.b.h. ($\overline{Dg}$) is smaller than NORMAL (fig. 4) for the number of trees present. The degree of understocking decreases as the trees grow. A *uniformly* understocked stand has adequate crop trees--trees that will reach merchantable size--but fewer excess trees than has an average stand. This may be due to either numerous *small* openings within the stand or a uniformly missing size component of small (generally younger) trees.

If, for example, a stand has 1,000 trees per acre (2,470 per ha) with well-distributed crop trees, it will *likely* develop in a manner similar to that shown in figure 29. The stand will reach MAXIMUM at a $\overline{Dg}$ of about 4.3 inches (10.9 cm). At about this time, the smaller trees will become suppressed and some will die; thus, the stand will slowly approach NORMAL through a combination of growth and mortality. When the stand with 1,000 trees per acre (2,470 per ha) reaches MAXIMUM, the largest 400 trees per acre (990 per ha) will have a $\overline{Dg}$ of about 5.1 inches (13.0 cm); the latter must then grow to 8.0 inches (20.3 cm) at the age of "first possible" commercial thinning. These 400 trees per acre (990 per ha) will have grown with less than average competition during part of their life and, thus, reach this size at a younger age. By the time the stand is ready for commercial thinning, it will for all practical purposes have the characteristics of a fully stocked stand.

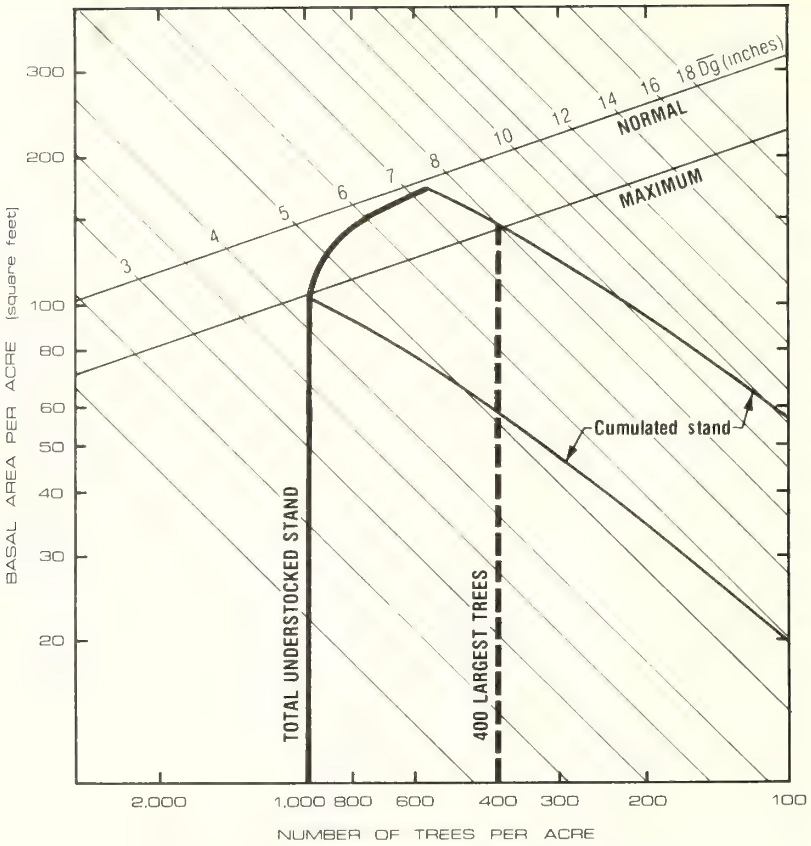

Figure 29.--Typical development of a uniformly understocked stand.

With our assumptions, the effects of this past understocking on merchantable yield should be reflected entirely in the age and site index at time of the first commercial thinning. Therefore, once this age and site index are known or estimated, one can predict future development of the *merchantable* portion of the stand. Each year gained in age at first possible commercial thinning will add about 1 to 2 percent to merchantable volume yield.

The major gain in age will occur prior to the time the stand reaches MAXIMUM--when crop trees have less than normal competition; there will be a slight additional gain thereafter, since trees will be younger than normal for the site. The gain, relative to the normal time required, will decrease as number of trees increases. With 1,000 trees per acre (2,470 per ha), we expect a gain of about 6.5 percent. This means a gain of about 1 year on the best sites and up to about 2.5 years on poorest sites, for stands having the same current site index.

Not all uniformly understocked stands will, however, behave in this manner. If tree size is very uniform, due to minimal variation in factors contributing to variation in size--age, genotype, and microsite--the stand may not thin itself adequately after reaching MAXIMUM. It will then become *overstocked*, with subsequent detrimental effects on stand development.

OVERSTOCKED STANDS

An overstocked stand is one in which $\overline{Dg}$ is larger than NORMAL for the number of trees present. One possible cause of this has already been noted. If a stand is very uniform, there will be little crown class differentiation; thus, few trees will be lost to mortality and most trees will continue to increase in size--at a reduced rate (fig. 15). When substantial mortality finally does occur in such stands, it tends to remove fairly large groups of trees rather than scattered individuals; this creates large openings and results in a loss of some of the crop trees. Thus, growth per acre is subsequently *less* than that of the average natural stand of the same site and age. Excessive overstocking may also cause a reduction in height growth. Gains from precommercial thinning in such a stand would, thus, be greater than gains from thinning an average natural stand of the same site and age.

Another possible cause of overstocking has much less impact on subsequent stand development. Even in stands where stand structure closely approximates that of average stands, mortality is erratic instead of following a smooth trend as in average stands. Commonly, a few years may pass in which there is little mortality; suppressed trees remain alive (although they do not grow), causing the stand to become overstocked. Then a drought or other such climatic variable will trigger heavy mortality in one year. This removes the accumulation of suppressed trees which "normally" might have died previously and, likely, also some which normally might not die until later. This erratic loss of suppressed trees will, generally, have little effect on development of the rest of the stand.

NONCONSTANT SITE INDEX

If height growth does not follow the average pattern relative to stand age, site index will not be a constant. Thus, it is not uncommon for site index to increase or decrease as the stand becomes older. If site index is increasing (relative to ours), volume growth per acre will be greater than with a constant site index; if site index is decreasing, volume growth will be less. The approximate magnitude of the effect can be estimated. For example, if site index increases from 170 to 180 as the stand grows from ages 30 to 60, we estimate that total cubic volume growth during this period will be about 13 percent greater than if site index remained at 170, and about 5 percent greater than if it had always been 180.

IRREGULAR STANDS

Other than these rather systematic deviations from the average natural stand, there are irregularities in stand composition. One such irregularity is the presence of *large* openings within the stand which are nonproductive. There is, however, a wide gray area between these large openings and the small openings discussed previously. Trees bordering on openings will grow more rapidly than if they were completely surrounded by competitors, but not enough to offset the missing crop trees. Each such situation is unique and must be so evaluated.

Another irregularity is the presence of other species. All the foregoing assumes pure Douglas-fir. If the trees within a stand include other species, both yields and recommended spacing of trees might be quite different. The effects of inclusions of other species and other irregularities in stand composition are beyond the scope of this paper.

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Appendix

GLOSSARY

Age: total age from seed.

Average d.b.h. ($\overline{Dg}$): Diameter at breast height of tree of average basal area. May refer to either total stand or a specified component of the stand.

Average natural stand (natural stand): A stand having the characteristics described in the section entitled "natural stands." These stands may also be called "normal" stands.

Crop trees (merchantable component): Trees which have attained, or are expected to attain, a specified d.b.h.

Cumulated-stand curve: A curve showing the cumulated contribution of largest trees to total number and basal area per acre as successively smaller trees are added.

CVTS: Cubic volume of total stems, including stump and tip.

CV4: Cubic volume of stems exclusive of (1) tip above a 4-inch d.i.b. and (2) stump below 1 foot or one-tenth of total height, whichever is lower.

d/D ratio: The ratio of average d.b.h. of cut trees to average d.b.h. of all merchantable trees before thinning.

DFIT: A stand simulator constructed to provide detailed output regarding managed-stand yield.

$\overline{Dg}$: See "average d.b.h."

dm (minimum merchantable d.b.h.): The smallest d.b.h. at which a tree is considered to be of merchantable (marketable) size.

G: Basal area per acre; may refer to either total stand or specified component of the stand.

Gross growth (growth per acre): Actual growth of all trees included at start of period, *not* reduced by mortality. May refer to the total stand or to specified component of the stand.

Gross production (gross yield): Total volume, or basal area, produced by the stand since its origin, including that lost to mortality or cutting. May refer to either total stand or to specified merchantable component.

Gross yield: See "gross production."

IV5: International board-foot volume of stems exclusive of (1) tip above 5-inch d.i.b. and (2) stump as for "CV4"; 1/4-inch kerf.

M.a.i.: Mean annual increment.

MAXIMUM: Defined by figure 5 and corresponding text. (1) $\overline{Dg}$, N, and G at which the maximum number of trees larger than a specified d.b.h. is reached in average natural stands; (2) the approximate maximum stocking level to which a given number of merchantable trees should be grown in a managed stand.

Merchantable component: See "crop trees."

Merchantable...: Pertains to merchantable component of stand; dependent on measure of volume.

Minimum merchantable d.b.h.: See "dm."

N: Number of trees per acre; may refer to either total stand or specified component of the stand.

Natural stand: See average natural stand.

Net yield: Excludes volume lost to mortality; may refer to either total stand or specified merchantable component.

NORMAL: Defined by figure 4 and corresponding text. A stand-density index; $\overline{Dg}$, N, and G of total average natural stand.

RECOMMENDED RESIDUAL (or RECOMMENDED): The minimum stocking level to which the merchantable portion of a stand will be reduced at each thinning.

Site index: Average height of dominant and codominant trees at age 100, if height growth follows the normal pattern.

Submerchantable trees: Trees which are expected to die without attaining the minimum merchantable d.b.h.

SV6: Scribner board-foot volume of stems exclusive of (1) tip above 6-inch d.i.b. and (2) stump as for "CV4."

VARIABLES AND RELATIONSHIPS EXAMINED

Plantation
Precommercial thinning
Commercial thinning
Cubic volume growth (ΔV)
Potential $\Delta V = f(\text{site, age})$
Reduced ΔV with thinning
Production by total stand
Production by stand components
$V = f(\text{height})$
Height growth (ΔH)
Improved ΔH w/early spacing
$\Delta\ \overline{Dg}$ of total stand
$\Delta\ \overline{Dg}$ of stand components
$\overline{Dg} = f(H)$; over time
D.b.h. $= f(H)$ at given times
$\overline{Dg}$, N, G of total stand
$\overline{Dg}$, N, G of stand components
Cumulated-stand curve
Mortality, total stand
Mortality, stand components
Stagnation

```
                                        SAMPLE DFIT PRINTOUT

                                            PROGRAM  DFIT

                                 DOUGLAS-FIR MANAGED YIELD TABLES

                                            SITE INDEX=140.0 (100-YEAR BASIS)
 THE CONTROL CARD SPECIFIES THAT
       DIAMETER OF THE MERCHANTABLE PART OF THE STAND AT THE FIRST POSSIBLE COMMERCIAL THINNING IS  8.00 INCHES.
       THE MINIMUM MERCHANTABLE DBH IS  6.00 INCHES.
       THE STAND HAS NOT HAD A PRECOMMERCIAL THINNING.
       THE THINNING INTERVAL IS  10 YEARS.
       NUMBER OF COMMERCIAL THINNINGS=  2.
       TOTAL AGE AT HARVEST=  60 YEARS.
       HARVEST STUMPAGE=$  150.00 PER THOUSAND BOARD FEET SCRIBNER.
       THINNING STUMPAGE=$  120.00 PER THOUSAND BOARD FEET SCRIBNER.
       DISCOUNT RATE= .0600.


OM +                                                    *                                          *         G1/
ODOM                      MEAN    MEAN    MEAN          *        VOLUME     PER      ACRE          *  TREES   PER   CURRENT      DISC       CUM
IGHT      STAND            DBH      G1/    VOL    VOL/G1/*             4-INCH     6-INCH     6-INCH *    PER  ACRE     PRICE     PRICE     PRICE
FEET    COMPONENT       INCHES   SQ FT   CU FT   RATIO *  CU FT      CU FT INTL 1/4 2/  SCRIB 2/ *   ACRE SQ FT         $         $         $
73.5    FIRST POSS        7.00   .2673    7.52   28.15 *   4826                                  *  641.5 171.4

73.7    TOTAL BEFORE      7.02   .2687    7.58   28.20 *   4841       4054      17484       8916 *  639.0 171.7
        SUBMERCH          4.89   .1303    3.12   23.92 *    738        440        872            *  236.8  30.9

        MERCHANTABLE      8.01   .3502   10.20   29.14 *   4103       3614      16612       8916 *  402.1 140.8      1337      1337      1337
        CUT               8.01   .3497   10.19   29.13 *   1367       1204       5533       2967 *  134.2  46.9       356       356
        MERCH LEAVE       8.02   .3504   10.21   29.14 *   2736       2409      11079       5949 *  267.9  93.9
        TOTAL LEAVE       6.73   .2471    6.88   27.85 *   3474       2850      11950       5949 *  504.7 124.7

        SUM GROSS                                      *   4841       4054      17484       8916 *        171.7
        SUM MERCH                                      *   4103       3614      16612       8916 *        140.8
        SUM OF CUT        8.01                         *   1367       1204       5533       2967 *  134.2  46.9


        VOL GROWTH                                     *   2322                                  *
        SUBMERCH MORT     4.82   .1266    3.00   23.72 *    504        292        525            *  167.9  21.3

91.6    TOTAL BEFORE      9.27   .4687   15.71   33.51 *   5291       4856      25264      17705 *  336.9 157.9
        SUBMERCH          5.05   .1393    3.56   25.54 *    245        157        222            *   69.0   9.6

        MERCHANTABLE     10.07   .5535   16.84   34.03 *   5046       4699      25042      17705 *  267.9 148.3      2656      1483      1939
        CUT               9.19   .4602   15.32   33.30 *   1343       1234       6338       4228 *   87.6  40.3       507       283
        MERCH LEAVE      10.48   .5989   20.54   34.30 *   3703       3465      18703      13477 *  180.3 108.0
        TOTAL LEAVE       9.39   .4717   15.84   33.58 *   3948       3622      18926      13477 *  249.2 117.6

        SUM GROSS                                      *   7163       6353      31323      20672 *        226.1
        SUM MERCH                                      *   6414       5903      30575      20672 *        195.2
        SUM OF CUT        8.49                         *   2711       2438      11872       7195 *  221.9  87.3


        VOL GROWTH                                     *   2861                                  *
        SUBMERCH MORT     4.98   .1354    3.43   25.34 *    163        102        121            *   47.5   6.4

10.1    TOTAL BEFORE     12.49   .8503   32.94   38.74 *   6646       6349      37827      30349 *  201.8 171.6
        SUBMERCH          5.21   .1480    4.02   27.16 *     86         58         73            *   21.5   3.2

        MERCHANTABLE     13.09   .9341   36.39   38.96 *   6560       6290      37754      30349 *  180.3 168.4      4552      1124      1764

10.1    HARVEST          13.09   .9341   36.39   38.96 *   6560       6290      37754      30349 *  180.3 168.4

O TOTALS

        SUM GROSS                                      *  10023       9181      50345      37544 *        286.5
        SUM MERCH                                      *   9270       8729      49626      37544 *        255.6
        SUM OF CUT       10.80                         *   9270       8729      49626      37544 *  402.1 255.6
```

1/ Basal area.

2/ Board feet.

SAMPLE DFIT PRINTOUT - Continued

```
                                    SUMMARY TABLE

       DOM +                          *                                            *
TOTAL CODOM                    MEAN  *          VOLUME    PER    ACRE             *   TREES     G2/
 AGE  HEIGHT      STAND        DBH   *                4-INCH   5-INCH       6-INCH *    PER      PER
YEARS  FEET     COMPONENT    INCHES*   CU FT     CU FT    INTL 1/4 1/   SCRIB 1/ *   ACRE     ACRE
  36     74     TOTAL BEFORE   7.02 *   4841      4054      17484          8916 *   639.0    171.7
                MERCHANTABLE   8.01 *   4103      3614      16612          8916 *   402.1    140.8


  46     92     TOTAL BEFORE   9.27 *   5291      4856      25264         17705 *   336.9    157.9
                MERCHANTABLE  10.07 *   5046      4699      25042         17705 *   267.9    148.3


  60    110     TOTAL BEFORE  12.49 *   6646      6349      37827         30349 *   201.8    171.6
                MERCHANTABLE  13.09 *   6560      6290      37754         30349 *   180.3    168.4
```

```
                                                NATURAL STAND TABLE

                                                  SITE INDEX=140.0 (100-YEAR BASIS)

     DOM +                                                   *                                                *         G2/
TOTAL CODOM                       MEAN    MEAN    MEAN                      VOLUME    PER    ACRE             *  TREES   PER   CURRENT  DI
AGE  HEIGHT      STAND            DBH      G2/    VOL      VOL/G2/*              4-INCH    5-INCH      6-INCH  *   PER   ACRE   PRICE   PR
YEARS  FEET      COMPONENT       INCHES   SQ FT   CU FT   RATIO *   CU FT     CU FT   INTL 1/4 1/  SCRIB 1/  *  ACRE  SQ FT     $

 36    73.7     TOTAL              7.02   .2687    7.58   28.20 *   4841       4054      17484        8916   *  639.0 171.7
                SUBMERCH           4.89   .1303    3.12   23.92 *    738        440        872               *  236.8  30.9
                MERCHANTABLE       8.01   .3502   10.20   29.14 *   4103       3614      16612        8916   *  402.1 140.8        1337



                SUBMERCH MORT      4.82   .1266    3.00   23.72 *    504        292        525               *  167.9  21.3
                MERCH MORT         6.79   .2513    7.35   29.25 *    295        245       1011         388   *   40.2  10.1


 46    91.6     TOTAL              9.13   .4542   15.22   33.51 *   6559       5999      30740       20967   *  430.9 195.7
                SUBMERCH           5.05   .1393    3.56   25.59 *    246        157        248               *   69.0   9.6
                MERCHANTABLE       9.71   .5142   17.44   33.92 *   6313       5842      30492       20967   *  361.9 186.1        3145



                SUBMERCH MORT      4.98   .1354    3.44   25.39 *    163        102        139               *   47.5   6.4
                MERCH MORT         7.63   .3176   10.61   33.41 *    917        808       3697        2064   *   86.4  27.5


 60   110.1     TOTAL             11.69   .7458   28.89   38.74 *   8581       8159      47504       37072   *  297.0 221.5
                SUBMERCH           5.21   .1480    4.04   27.33 *     87         59         81               *   21.5   3.2
                MERCHANTABLE      12.05   .7925   30.83   38.90 *   8494       8100      47422       37072   *  275.5 218.3        5561
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[1] Board feet.

[2] Basal area.

GPO 999-537

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COPING WITH UNCERTAINTY-- A CONCEPTUAL APPROACH FOR TIMBER MANAGEMENT PLANNING

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Abstract

Timber management planning is usually done with implicit recognition of risk and uncertainty about future events. This recognition is acknowledged by following strategies such as frequent replanning and maintaining options. In this paper, we discuss various approaches to decisionmaking that explicitly recognize risk and uncertainty, and present one such approach to timber management planning. This approach provides a framework for making a consistent set of timber management planning assumptions.

KEYWORDS: Timber management planning.

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INTRODUCTION

The process of decisionmaking is invariably concerned with the future since decisions made now can only have consequences in the future. Unfortunately, the decisionmaker is seldom absolutely certain of the consequences of his decisions because the future is uncertain. Decision theory provides some helpful approaches to decisionmaking under risk and uncertainty.

This paper shows how some concepts developed in decision theory can be used in making assumptions for timber management planning under conditions of risk and uncertainty. This will be accomplished by a brief review of the theory and a discussion of what the attitude of public agencies toward risk and uncertainty should be. We also present an approach that uses an explicit attitude toward risk and uncertainty in a timber management planning context. Finally, we develop an approach for determining policies that are consistent with a given attitude.

DECISION THEORY

According to decision theory, the appropriate model for decisionmaking depends on the degree of knowledge concerning the future and the decisionmaker's attitude toward uncertainty. We can illustrate this point by the example shown in table 1. Here, each of three alternatives, A, B, and C, can have one of three outcomes or consequences, 1, 2, or 3, depending on the state of nature or assumptions that will actually prevail in the future. In this section weather is used as an example of a state of nature. For example, table 1 might represent the percentage of regeneration losses that would occur in the first year for three planting methods and various weather conditions as states of nature. If we know state 3 will actually occur, then we choose planting method B since it minimizes the loss. On the other hand, we may not be sure of which weather pattern will occur, and then we may wish to use a more complex decision model in an attempt to minimize the loss.

A wide range of decision models exists. At one extreme there is no knowledge at all about which state will actually occur; thus, we are completely ignorant about which consequence will occur for a given alternative. For conditions such as this, several decision rules have been proposed, none of which is clearly superior to the others in all cases.

If we are pessimistic we might choose the minimax criterion. This involves selecting the alternative that minimizes the maximum possible loss; that is, for each alternative shown in table 1, the worst possible loss is assumed. For alternative A this would be the 14-percent loss that would occur under the first weather pattern. The other worst possible losses are shown in the fifth column of the table. We select the planting method that produces the least of these worst possible losses. In our example this would be alternative C with a loss of 9 percent. This alternative would leave us with the least loss, if we assume that the worst possible weather occurs.

If we are optimistic we might choose the minimin criterion. This involves selecting the alternative that minimizes the minimum possible loss; that is, for each alternative the least possible loss is assumed. The procedure involves selecting the alternative with the smallest of the least possible losses shown in the sixth column of table 1, or planting method A in our example. This alternative would leave us with the least loss, if we assume that the best possible weather occurs.

The Laplace criterion which falls somewhere between these extremes of pessimism and optimism requires that the alternative with the lowest average loss over all states of nature be chosen. The average is calculated by summing the losses for each alternative over the states of nature and dividing by the number of states of nature. For example, the sum of the losses for alternative B is 29, which divided by three, equals the average loss (9.7) shown in the last column of table 1. The least of these average losses is produced

Table 1--*Hypothetical regeneration losses associated with various planting alternatives and states of nature*

Alternative planting methods	State of nature, weather pattern			Worst possible loss	Least possible loss	Average loss
	1	2	3			
				Percent		
A	14	2	8	14	2	8.0
B	4	20	5	20	4	9.7
C	8	9	6	9	6	7.7

Table 2--*Hypothetical regrets associated with various planting alternatives*

Alternative planting methods	Regret calculation by state of nature			Largest regret
	1	2	3	
		Percent		
A	14-4=10	2-2= 0	8-5=3	10
B	4-4= 0	20-2=18	5-5=0	18
C	8-4= 4	9-2=7	6-5=1	7

Table 3--*Hypothetical expected losses associated with various planting alternatives*

Alternative planting methods	State of nature			Expected loss
	1	2	3	
			Percent	
A	14	2	8	[1]6.2
B	4	20	5	12.3
C	8	9	6	7.9
Probability of occurrence	0.2	0.5	0.3	--

[1] Expected loss = 0.2 x14 + 0.5 x 2 + 0.3 x 8 = 6.2. Others are calculated in a similar manner.

by alternative C which would be the correct choice if this criterion is used. Contrary to the previous criteria, this criterion implies that we feel each state is equally likely to occur.

A final criterion for situations of complete uncertainty reflects the economists' concept of opportunity cost and is called minimax regret. The method suggests that the smallest loss for each state be subtracted from every other loss for that state; then the largest resulting values or regrets for each alternative are compared and the alternative with the smallest or best value is chosen. Table 2 shows the regret calculations for our example. Each regret expresses the loss we would experience from choosing the wrong alternative when a given state of nature occurs. We only need to apply the previously discussed minimax criterion to these regrets to choose alternative C.

It should be emphasized that the examples and criteria deal with consequences expressed as losses, but converse criteria exist for consequences expressed as gains; for example, minimax becomes maximin. More complete descriptions of these models are available in any standard text on decision theory such as Halter and Dean (1971), Luce and Raiffa (1957), and Schlaifer (1959).

The preceding cases assumed that the decisionmaker had no knowledge concerning the future and was not willing to make judgments. Usually, we have expectations or evidence concerning the future based on past experience.

The other extreme to the no information situation just discussed is complete information regarding the future. Here, we know what consequence will occur for each alternative and we can choose accordingly. This decisionmaking under certainty is also seldom the case. For ease in decisions, however, certainty is often assumed. For example, the decisionmaker may assume that wood will be used in the future or that the present price of timber indicates the future real price many years hence. Assumptions such as this are helpful in reducing the decisionmaker's workload, but they ignore the risk or uncertainly that surely exists.

Other decision criteria reflect less extreme assumptions regarding our knowledge of the future. Decisionmaking under risk assumes that probabilities of occurrence may be assigned to the various states of nature and that we are neutral toward alternative levels of risk. The probabilities may be based either on past experimental evidence projected to the future or on intuitive feelings regarding the shape of the future probability distribution.

In our regeneration loss example, we might have used historical weather data to arrive at probabilities of occurrence for each of the three weather patterns considered. The last row of table 3 shows the hypothetical probability for each state of nature arrived at in this manner. If we are neutral toward levels of risk, the expected loss may be calculated for each alternative by multiplying the loss associated with each state of nature by its probability of occurrence and then summing these values over the three states of nature. The results of these computations are shown in the last column of table 3. To minimize our losses in the long run, we would choose the planting method with the least expected loss (alternative A).

If for some reason we are uneasy about using expected values in our decisions, another procedure exists. We can assume that the state of nature with the highest probability of occurring will occur. When we do that, we return to decisionmaking under certainty. In our example in table 3, state 2 has the highest probability and alternative A would minimize the losses under this state. This procedure is similar to choosing the mode instead of the mean to express central tendency in a distribution and might be applicable for one-time decisions.

As the foregoing discussion indicates, the choice of decision criteria depends on the decisionmaker's attitude toward the data or lack of data. For example, in a no data case the choice of criterion may depend on whether or not the decisionmaker feels he can place subjective weights on the states of nature. Or in a sample data case, he may decide to view the future state as certain or as involving a range of probabilities, depending on his own views. Thus, how the decisionmaker views the world is an important element in his decisionmaking process because it determines the criterion he is likely to select. This brings us to a discussion of what the proper attitude toward risk and uncertainty, particularly in public agencies, should be.

ATTITUDE OF PUBLIC AGENCIES TOWARD RISK AND UNCERTAINTY

Although there is no universally agreed upon attitude toward risk and uncertainty in public agencies, a few schools of thought have been developed. One line of reasoning, supported by Hirshleifer (1965, 1966) and others, maintains that the public sector ought to act like the private sector; that is, in the private sector of the economy investments are made that maximize present net worth subject to adjustments for risk and uncertainty. Hirshleifer argues that ignoring these adjustments for risk and uncertainty in the public sector will result in overinvestment in public programs at the expense of private investment opportunities.

Another viewpoint states that the Government, because of its size and unique position in the economy, should ignore uncertainty and act as if it were indifferent to risk. The Government should assume that the outcomes are certain and should maximize present net worth because its large size allows it to pool its risks (Samuelson and Vickrey 1964) or to disperse them (Arrow and Lind 1970), depending on how the system is viewed. The Government can also control the level of risk and uncertainty in some cases because of its economic power.

A third position by economists proposes that the Government should ignore the market and the private sector in responding to risk and uncertainty because of the imperfections in the system. Also, it is argued that the market does not reflect the proper public attitude which should be set through the political process rather than the economic process. This view, although somewhat more realistic than the previous two in recognizing market imperfections, does not indicate what the proper attitude should be nor what guidelines the political process should follow in determining it.

Which of these three positions is most desirable depends on one's view of the world. If market forces are believed to provide the socially efficient solution they theoretically do under the perfectly competitive model, then the first two positions are preferred. Which of these two is appropriate depends on whether one believes that misallocation of resources will occur if the Government acts according to its unique position in the market. If misallocation will occur the first viewpoint is most appropriate. If one believes, however, that the conditions necessary for the perfect competition model to apply do not exist, then perhaps the alternative in which policy dictates the Government's attitude toward risk and uncertainty is most appropriate. Given the externalities, lack of information, few firms, and Government intervention in the present resource markets, this view appears to have some merit provided the Government knows what is socially desirable.

Unfortunately, Government officials seem reluctant to establish an explicit policy toward risk and uncertainty or they are unable to. The Water Resources Council, which is as progressive as any bureaucracy in recognizing decision-making principles, has implicitly chosen the second position discussed above. It recommends using an interest rate based on the average yield of "interest bearing marketable securities of the United States" (Federal Register, Sept. 10, 1973, 38(174):24822). Since Government securities are regarded as riskless, this statement implies that the Government should act as though risk and uncertainty do not exist. Both Congress (Federal Register, Aug. 14, 1974, 39(158): 29243) and the U.S. Department of Agriculture (1974) have concurred. This conclusion implies that decisions in Forest Service timber management planning should be based on the assumption that the most likely state of nature will occur. As we shall point out shortly, however, this may not always be the case.

RISK IN TIMBER MANAGEMENT PLANNING

Little explicit recognition of risk and uncertainty occurs in timber management planning in the U.S. Forest Service. Deterministic solutions are almost always used, and a range of outputs to account for uncertainty is seldom included.

Risk and uncertainty in timber management planning could be, and often are, accounted for by frequent replanning and by maintaining options. Explicit consideration of risk and uncertainty however, would make possible fuller communication and a more consistent approach to timber management planning. A brief discussion of frequent replanning and of maintaining options is followed by a thorough treatment of developing an explicit risk management strategy.

FREQUENT REPLANNING

Timber management plans are redone at 10-year intervals, but they are usually reviewed more often. Most plans state that they will be revised if significant changes in allowable cut are anticipated. These changes might be due to land use decisions, widespread tree mortality, new yield tables, new environmental constraints, etc. Thus, frequent replanning allows new situations to be incorporated into the management plan and provides an adaptive response to uncertainty.

MAINTAINING OPTIONS

Frequent replanning is useless unless the manager has some options. Thus, another response to uncertainty is to preserve the opportunity to respond to alternative futures quickly. In timber management, one method of retaining options is maintaining high levels of inventory. A high inventory allows the manager to respond quickly since he can either increase or decrease the harvest as required. On the other hand, under low levels of inventory, he may only be able to reduce the harvest level in the short run because of the time required for trees to grow.

DEVELOPING A RISK MANAGEMENT STRATEGY IN TIMBER MANAGEMENT PLANNING

Explicit recognition of risk and uncertainty in timber management planning is based on the approach illustrated in the discussion of table 1. For clarity, however, we will use a timber management planning example and go through two steps to get a table equivalent to table 1.

The first step is to prepare a table that shows the differences in first decade harvest levels for alternative sets of assumptions and states of nature. The alternative sets of assumptions include the combinations of assumptions about yields, level of investment, etc. that we might make in preparing the timber management plan. The states of nature include the possible actual outcomes for those assumptions. The values in table 4 are calculated by taking the differences in the harvest levels for each combination of assumptions and states of nature. The assumptions for the harvest levels calculated for alternatives A, B, and C correspond with the assumption for the states of nature 1, 2, and 3. Thus, when the state of nature is the one assumed, H_A (the harvest level with assumption set A) and H_1 (the harvest level with state of nature 1) will be equal and that value will be zero. We define the set of assumptions used in this situation as perfect assumptions.

The second step in constructing a table equivalent to table 1 is to convert the differences in table 4 into social losses. Later we will show that all nonzero values in table 4 represent social losses. Table 5 is an example of a loss table prepared from table 4. It is slightly different in appearance from table 1 because it has zeros on the diagonal representing situations for which the assumptions exactly match the outcome. Table 5 is, however, equivalent to table 1 and can be interpreted in the same way. The same decision rules that were discussed in connection with tables 1 and 3 could be applied to table 5. Because each state of nature has one outcome with a zero loss, table 5 can also be interpreted as a table of regrets like table 2.

Table 4--*Differences in harvest levels with alternative sets of assumptions and states of nature*[1/]

Alternatives	State of nature		
	1	2	3
A	$H_1 - H_A$	$H_2 - H_A$	$H_3 - H_A$
B	$H_1 - H_B$	$H_2 - H_B$	$H_3 - H_B$
C	$H_1 - H_C$	$H_2 - H_C$	$H_3 - H_C$

[1/] H_A, H_B, and H_C are harvest levels calculated when assumption sets A, B, and C are used. H_1, H_2, and H_3 are harvest levels that would have been calculated if assumptions corresponding to states of nature 1, 2, and 3 had been used.

Table 5--*Losses associated with alternative timber planning assumptions and states of nature*[1/]

Alternative	State of nature		
	1	2	3
	- - - -	Values	- - - -
A	0	4	7
B	2	0	3
C	9	6	0

[1/] Values represent units of social loss. They can be thought of as dollar equivalents reflecting how much society would be willing to pay to avoid the loss.

We will begin our discussion of a risk management approach to timber management planning by first looking at timber management planning with perfect knowledge of the future. We will then introduce risk and show how that affects the outcome. Then we will provide a framework for developing a strategy intended to improve the outcome when we lack perfect knowledge.

Although we illustrate this framework with quantitative relationships, we do not expect you to try to numerically estimate such relationships. They are provided to facilitate understanding of the concepts. We believe that an understanding of the concepts can help timber management planners decide how planning assumptions should be made to best meet agency objectives. We believe that timber management planning policymakers can benefit from this perspective even if the relationships we discuss cannot be quantified. For those who wish to quantify the uncertainties and use those estimates directly in the decisionmaking process, some approaches are available.1/ 2/

TIMBER MANAGEMENT PLANNING WITH PERFECT KNOWLEDGE

Before the timber management planner can calculate an allowable harvest level, he must be given a policy on the desired pattern of flow over time or he must determine one. This pattern is the one that the agency deems on behalf of society to be socially optimal; it could be nondeclining flow, a maximum present value flow, or some other scheduling pattern.

The discussion throughout this paper implicitly assumes nondeclining flow as the scheduling pattern deemed socially desirable. Our approach could be applied to any other scheduling pattern that is affected by a new perception of the future. Our discussion is restricted to nondeclining flow, however, for ease of presentation and because it relates most closely to current public policy.

Given a desired scheduling pattern and perfect knowledge of the future, the planner's job would be simple. Using assumptions that exactly correspond to future events (perfect assumptions), the planner calculates the allowable harvest. The result is that there is no need for replanning, there is no need for maintaining options, and the desired harvest scheduling pattern is exactly achieved.

Timber management planning with perfect knowledge is obviously an impossible ideal; future yields are uncertain, future funding is uncertain, future land withdrawals are uncertain, etc.

TIMBER MANAGEMENT PLANNING WITH IMPERFECT KNOWLEDGE

When imperfect assumptions are used in timber management plans, the actual outcome may differ from the desired outcome. When we change the assumptions to conform to our new expectations about the future, we get a new allowable harvest level that causes a deviation from the scheduling pattern desired. Figure 1 demonstrates this situation. The actual harvest follows the level calculated at time 0 until new information becomes available at time 1. The actual harvest then jumps to the level calculated at time 1. This is a deviation from the nondeclining flow pattern that would have been calculated if the knowledge gained at time 1 were available at time 0. Since there is a deviation from the nondeclining flow pattern deemed socially desirable, we must conclude that from that perspective we have incurred a social loss. This is true whether the adjustment is an increase or a decrease, since both cause a deviation from the scheduling pattern that was deemed desirable and that would have been followed if knowledge had been better.

1/ Weintraub, Andres. 1976. Forest management planning under uncertainty. 76 p. Oper. Res. Cent., Univ. Calif., Berkeley.

2/ Howitt, Richard E., Bruce L. Dixon, and William G. O'Regan. 1976. An application of stochastic control methods to the timber management of the Stanislaus National Forest. Annu. Rep. For. Serv. Res. Agreement No. 13-829. 82 p. Dep. Agric. Econ., Univ. Calif., Davis.

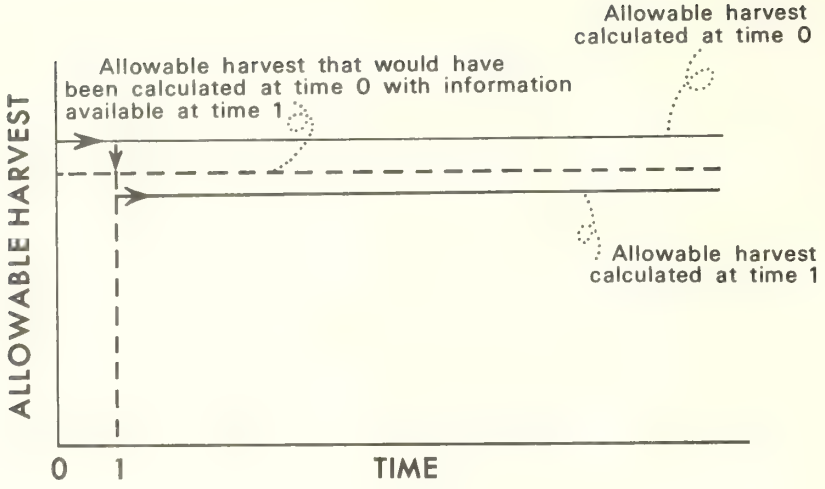

Figure 1.--Allowable harvest calculated at time 0 and at time 1 with new information. The three horizontal lines are planned harvest levels based on different assumptions. The arrows indicate the path of actual harvest.

Deviations from the desired pattern can occur whether the desired pattern is nondeclining flow, maximum present value flow, or some other pattern. It should be noted, however, that some scheduling patterns may be much more sensitive than others to certain kinds of new information. For example, nondeclining flow scheduling patterns may be very sensitive to assumed second rotation yields and not at all affected by near-term demand relationships. Scheduling patterns based on maximizing present value may be very sensitive to near-term demand relationships and only slightly affected by second rotation yields.

We conclude this section by pointing out that, in general, deviations from the desired scheduling pattern cannot be avoided. The nature of the deviations, however, can be affected by our choice of assumptions; that is, we can choose to have mostly harvest increases or mostly decreases. Developing a strategy for minimizing the social losses incurred with these deviations requires consideration of the nature of the social losses associated with deviations.

THE NATURE OF DEVIATIONS FROM DESIRED PATTERNS

When we overestimate future growth or utilization, we harvest more in the near-term than we would with perfect assumptions and have to make a downward adjustment in the future. When we underestimate future growth or utilization, we harvest less in the near-term than we would with perfect assumptions and we have to make an upward adjustment in the future. We view the adjustment that is made when the plan is recalculated as an index of the deviation from the desired scheduling pattern. From figure 1 we see that the actual deviation involves a period of overcutting from time 0 to time 1, followed by a period of compensating undercutting starting at time 1. To simplify the discussion, we will use only the magnitude and direction of the initial adjustment when the plan is recalculated in our discussion of the social losses.

If we were to look at the adjustments on all timber management plans when they were recalculated in the future, we would find numerous changes in harvest levels. Some plans would have harvest increases and some would have decreases. Some adjustments would be major and some would be minor. The large number of plans involved and the numerous factors that can affect allowable harvest levels would likely result in a frequency distribution of adjustments that would look something like figure 2. This example shows that 32 plans had harvest increases of up to 5 percent, 25 plans had increases of 5-10 percent, etc. There is no assurance, however, that the largest number of plans will fall near the zero adjustment. In fact, as we shall see later, it may be desirable to have the largest number of plans fall some distance away from the zero adjustment.

The frequency distribution in figure 2 can also be represented as a continuous probability distribution as in figure 3. In figure 3, the area under the curve represents all the plans. The proportion of the area under the curve such as the shaded area in figure 3A represents the proportion of the plans that have adjustments within the range of Y to Z. Figure 3 represents three possible outcomes for the aggregation of all timber management plans. Figure 3A represents a situation for which the average deviation for all plans is zero and half the plans have harvest increases and half have decreases. Since the average adjustment is zero, there is little or no adjustment in the national total allowable harvest even though there are positive or negative adjustments on most forests. The social losses associated with this pattern of deviations is therefore limited to those consequences that are determined by local and regional totals. Figure 3B represents a situation in which most plans have harvest increases when they are recalculated in the future. Figure 3C represents the opposite situation. In these two situations harvest totals change for the Nation as well as for most local areas. Therefore, the social losses associated with these patterns of deviations involve consequences determined by national totals as well as those determined by local and regional totals.

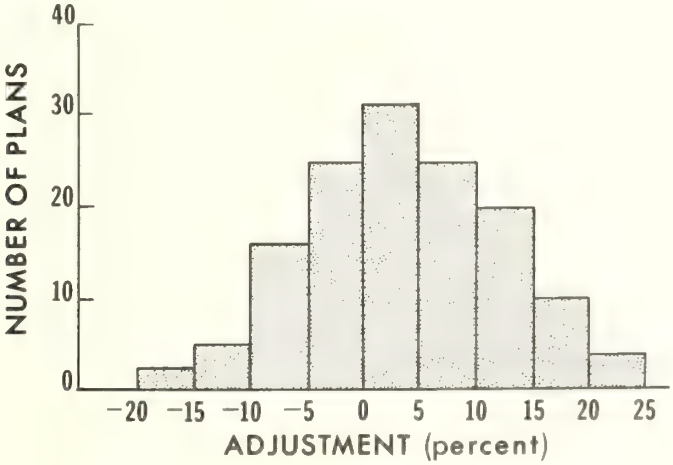

Figure 2.--Frequency distribution showing number of plans and magnitude of adjustment in allowable harvest.

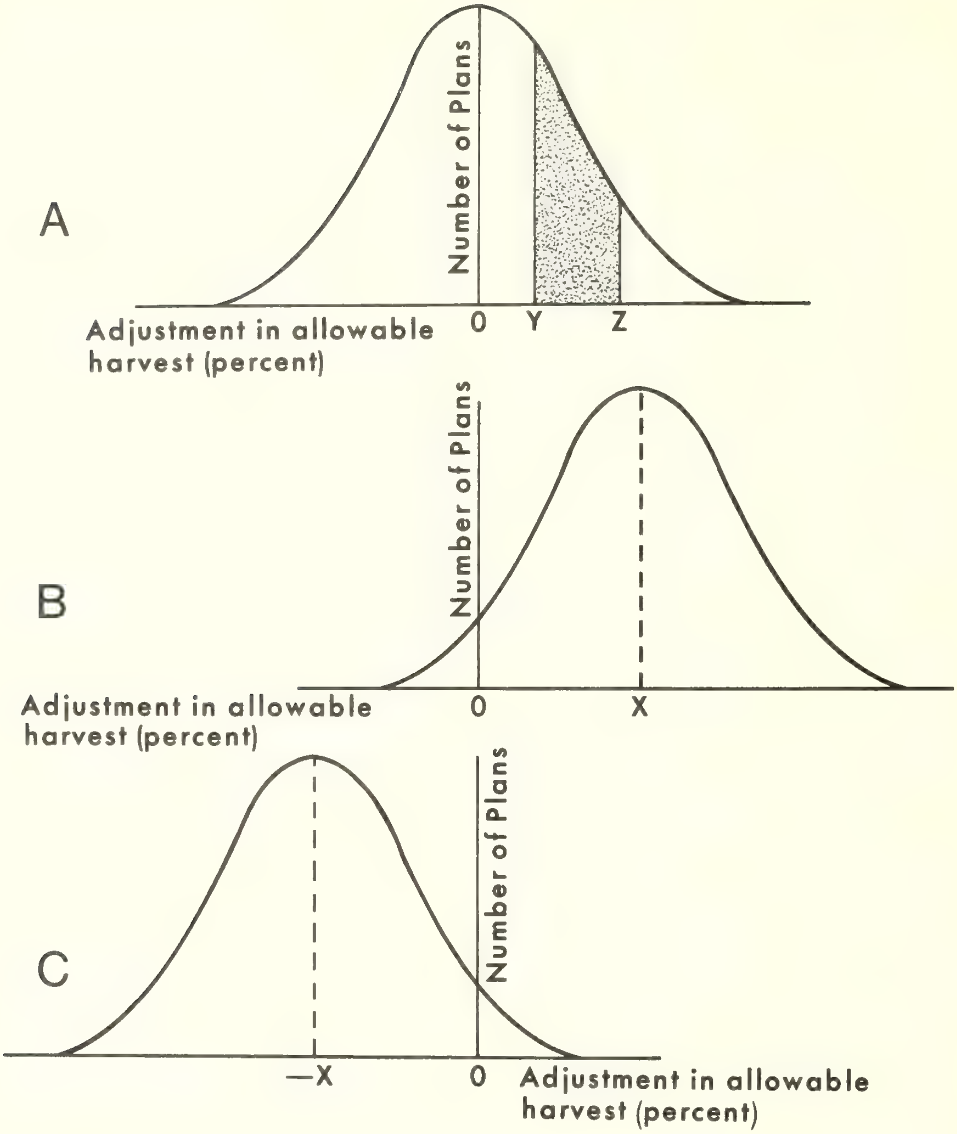

Figure 3.--Probability distribution of percent adjustments in allowable harvest levels.

THE NATURE OF SOCIAL LOSSES

We will now assert, and later show, that our policies about which assumptions to use in timber management planning will determine location of the probability distribution of deviations that result; that is, whether it will be more like figure 3A, 3B, or 3C. But first we want to discuss what the policymaker needs to consider in order to decide which pattern of distributions is preferable.

The distribution of deviations that is best for society depends on the nature of the social losses associated with deviations. One issue is whether or not the loss function is symmetrical; that is, whether the social loss from an X percent upward adjustment is the same as the loss from an X percent downward adjustment. Figure 4 shows two hypothetical loss functions. Loss function (b) is symmetrical and, other things being equal, would lead us to prefer that the probability distribution be centered around the zero adjustment as in figure 3A. Loss function (a) is nonsymmetrical and has higher losses associated with downward adjustments than with upward adjustments. In this case, other things being equal, we would prefer that most plans have a harvest increase when they are redone, as in figure 3B, in order to avoid the higher social losses associated with even small downward adjustments.

Another issue concerns the shape of the loss function. Figure 4 shows linear functions, but losses may not be directly proportional to deviations from the desired level. If large adjustments are proportionally more critical than small adjustments, we must pay greater attention to our policies to avoid the high losses associated with large harvest adjustments.

One fact about the nature of losses from upward adjustments and downward adjustments may be of interest to decisionmakers in assessing the magnitude of losses. When plans are recalculated and adjustments are indicated, the losses associated with harvest increases are all in the past, because the losses with harvest increases are opportunity costs of fiber and income forgone that could have been made available at an earlier time. Losses associated with harvest decreases begin immediately. These losses are associated with the compensating undercutting or the reduction in harvest that will occur.

The situation can also be viewed from the perspective of the time when the plan is prepared. From that perspective the losses associated with future harvest increases start immediately as forgone opportunities, and the losses of future decreases are postponed to the time when the new plan is prepared.

THE SOURCE OF SOCIAL LOSSES

The scheduling pattern deemed optimal is justified on the basis of the consequences of alternative scheduling patterns. The "Timber Harvest Scheduling Issues Study" (U.S. Department of Agriculture 1976) provides an analysis of the consequences of alternative harvest scheduling patterns. These consequences can be categorized as those that are determined primarily by national totals and those that are determined primarily by local or regional totals.

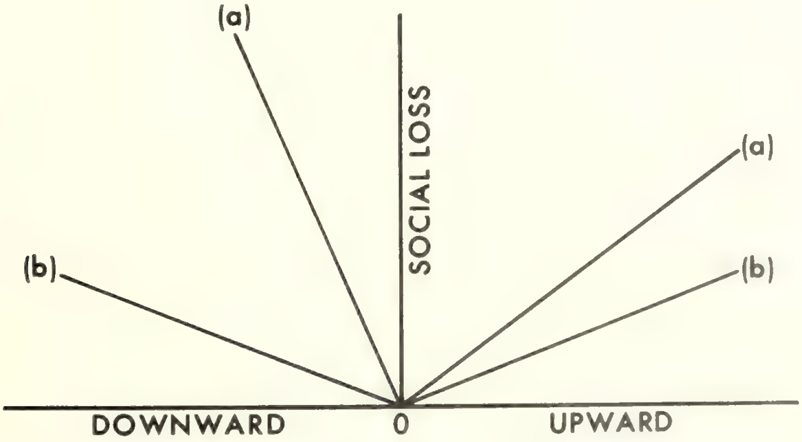

Figure 4.--Magnitude of social loss for upward and downward adjustments from desired schedule.

Some consequences determined primarily by national totals include changes in:

1. Product prices.
2. International trade.
3. Role of forests in meeting strategic objectives.
4. Income distribution as affected by prices and profits.
5. Substitution of wood for other materials and vice versa.
6. Effect on the aggregate stock of capital available to society.

Some consequences determined primarily by local or regional totals include changes in:

1. Local and regional economic impacts.
2. Effects on forest ecosystems.
3. Effects on nontimber benefits.
4. Income distribution as affected by employment and wages.
5. Effects on competitive structure of the wood-using industry.
6. Production costs and economic efficiency.
7. Effects on agency employment.

The above consequences provide a basis not only for choosing a desirable harvest scheduling pattern but also for evaluating the cost of deviations from that pattern. An evaluation of these consequences is one of the elements needed to determine policies dealing with risk and uncertainty that will give a pattern of deviations that is least objectionable.

DESIGNING RISK STRATEGIES

Once we have thought about the distribution of deviations, the loss function, and the desired location for the distribution, we can begin our discussion of designing risk strategies. We will first consider the case for which we have determined that we have a symmetrical loss function, as illustrated by (b) in figure 4. When we have a symmetrical loss function, the pattern of deviations shown in figure 3A will minimize the losses--the bulk of the adjustments is small where the loss is small. We still prefer to have no adjustments at all, but we are indifferent between positive and negative adjustments of the same magnitude. Because of this indifference, we will call the strategy, a neutral strategy. This situation is illustrated in a loss table (table 6). This loss table represents the losses for the aggregate effect of all timber management plans when they are recalculated in the future. It shows that the losses associated with harvest increases (conservative assumptions with neutral or liberal states of nature) are the same as the losses associated with reductions (liberal assumptions with neutral or conservative states of nature).

Table 6--*Losses when loss function is symmetrical and linear*

Assumption[1]	State of nature[2]		
	Conservative	Neutral	Liberal
	- - - - - - - - - -	Values[3]	- - - - - - - - - -
Conservative	0	1	2
Neutral	1	0	1
Liberal	2	1	0

[1] We define assumptions as conservative (liberal) if they are expected to result in a lower (higher) near-term harvest level than "most likely" assumptions. We define assumptions as neutral if they are "most likely."

[2] States of nature are defined as conservative, neutral, or liberal according to the set of assumptions to which they correspond.

[3] Values represent units of social loss. They can be thought of as dollar equivalents reflecting how much society would be willing to pay to avoid the loss.

Can we be assured of having the distribution of deviations centered around zero adjustment, as in figure 3A, by pursuing a neutral strategy? Our neutral strategy would be to use most likely estimates for all assumptions in the calculation of the allowable harvest. By so doing, our expectation would be that adjustments resulting from new perceptions of the most likely estimates would have an equal chance of being positive or negative. With a large number of assumptions and a large number of plans, we might expect the deviations to be essentially offsetting and the distribution of deviations to be centered around zero adjustment. In order to depend on the law of large numbers (central limit theorem), however, we must accept the assumption that the distribution of interest (in this case, the distribution of deviations) is a summation of independent events. This probably is not true. There probably are some assumptions whose errors could be regarded as independent; that is, the deviations are mainly the result of local random events and do not fall into a consistent pattern. There most certainly are some assumptions, however, that are not independent. For example, a shift in preference of the American people toward additional areas reserved from timber production could cause the large majority of plans to deviate in the same direction. Likewise, new technology in regeneration systems or mutations of a tree disease that made a major tree species susceptible to catastrophic loss would affect a large number of plans in the same direction. We conclude that the neutral strategy is the approach that gives the greatest probability of having the distribution of deviations center around zero. We must recognize, however, the possibility of significant events that will shift the distribution so it is not centered around zero. So, although the neutral strategy gives the greatest probability of having the distribution center around zero, that probability may be low.

The second risk strategy is appropriate where there is a higher loss associated with harvest decreases than with increases. Such a situation is illustrated in a loss table like table 7 where liberal assumptions lead to high losses unless the future state of nature closely corresponds to the assumptions. In this situation, we

Table 7--*Losses when loss from downward adjustment is greater*

Assumption[1/]	State of nature[2/]		
	Conservative	Neutral	Liberal
	- - - - - - - - - - Values[3/]	- - - - - - - - - - -	
Conservative	0	1	2
Neutral	3	0	1
Liberal	6	3	0

[1/] We define assumptions as conservative (liberal) if they are expected to result in a lower (higher) near-term harvest level than "most likely" assumptions. We define assumptions as neutral if they are "most likely."

[2/] States of nature are defined as conservative, neutral, or liberal according to the set of assumptions to which they correspond.

[3/] Values represent units of social loss. They can be thought of as dollar equivalents reflecting how much society would be willing to pay to avoid the loss.

are adverse to the chance of overcutting; that is, we want to play it safe with respect to harvest decreases because of the perceived high costs of such decreases. We can do this by intentionally undercutting. This is accomplished by using conservative assumptions that we expect on the average will result in a distribution of deviations as in figure 3B. By being sufficiently conservative, we can insure against the nonindependent events that could shift the majority of plans so that harvest decreases would be required.

The third risk strategy is appropriate where there is a higher loss associated with harvest increases than with decreases. Table 8 illustrates a case in which conservative assumptions lead to high losses unless the future state of nature closely corresponds to the assumptions. When the loss associated with harvest increases is greater than for decreases, we are adverse to the chance of undercutting; that is, we want to set an optimistically high harvest level, using liberal assumptions so that we will have very few harvest increases. We would expect the result to be like figure 3C where there is, on the average, a harvest decrease and there are few plans with increases. As with the second risk strategy, it is possible to insure against the nonindependent events by being sufficiently liberal.

Another approach to risk management deserves mention. If the conservative risk management strategy were the preferred one, it might be implemented in a different, perhaps simpler, way. Such a strategy might be implemented by taking the harvest schedule for the neutral strategy and applying a reduction factor to it. A rationale for this approach would be that the use of conservative assumptions at various stages in the plan preparation has a cumulative effect that is superconservative or perhaps just highly variable or unknown. Applying the risk management correction at the end of the calculation

Table 8--*Losses when loss from upward adjustment is greater*

Assumption[1]	State of nature[2]		
	Conservative	Neutral	Liberal
	- - - - - - - - - - -	Values[3]	- - - - - - - - - - -
Conservative	0	3	6
Neutral	1	0	3
Liberal	2	1	0

[1] We define assumptions as conservative (liberal) if they are expected to result in a lower (higher) near-term harvest level than "most likely" assumptions. We define assumptions as neutral if they are "most likely."

[2] States of nature are defined as conservative, neutral, or liberal according to the set of assumptions to which they correspond.

[3] Values represent units of social loss. They can be thought of as dollar equivalents reflecting how much society would be willing to pay to avoid the loss.

ties it less directly to the uncertainties related to that forest; however, it would make more explicit the amount of reduction for risk management objectives and would facilitate comparisons between forests. The same approach could be used to promote the liberal risk management strategy.

CONSISTENCY IN TIMBER MANAGEMENT PLANNING ASSUMPTIONS

If consistency is desired in timber management planning policies, the assumptions used in planning must be made consistent with the risk management attitude. The alternative assumptions that might be used will be categorized as consistent with a conservative (liberal) risk management strategy if they are expected to result in lower (higher) near term harvest levels than "most likely" estimates. We cannot definitively categorize all assumptions in this way because we do not know very accurately what is most likely in many cases. Table 9 is an attempt to categorize some reasonable assumptions as being consistent with a conservative or liberal risk management strategy. These assumptions are only points on a continuum of assumptions all of which are consistent with one of the three main risk management strategies.

An interesting exercise is to compare the risk management strategy positions outlined in table 9 with selected Forest Service policies in order to determine the Forest Service's position and its consistency. Although these policies may vary somewhat by Region and Forest, some implications can be drawn from table 10. In general, the current policies appear to be mildly liberal overall, and there is sufficient variation to question their consistency. This is an interesting result since many people feel that the Forest Service either should maintain or does maintain a consistently conservative attitude.[3] We recognize that others may use different definitions of conservative and liberal than the ones we use in table 10. Others may therefore reach somewhat different conclusions.

In summary, the role of risk and uncertainty in the analysis of alternatives can be important since projected harvest flows and their consequences may not be the actual flows and consequences. Although the Forest Service fails to explicitly consider risk and uncertainty in the manner outlined in this paper, it does make implicit responses involving frequent replanning, maintaining options, and developing implicit attitudes through their planning assumptions. It would be useful, however, to propose a national policy to insure consistency, and to open the policy to national debate and resolution.

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[3] This is illustrated by the following quote taken from the Congressional Record, October 1, 1976, p. E 5642, by Hon.George E. Brown, Jr.: "I would submit that we have charged the Secretary to be conservative in what he does" regarding the National Forest Management Act of 1976.

Table 9--*Assumptions used in timber management planning*

Item	Assumptions that characterize	
	Conservative risk management	Liberal risk management
Treatments	Include practices only if yields are proved by research studies under similar conditions.	Include practices even if yields are speculative
Energy	Exclude energy intensive practices that are vulnerable to changes in energy availability	Include practices that are feasible with current energy conditions
Return on investment	Include only practice-type site combinations that give a high rate of return	Include practices that are feasible today even if vulnerable to more restrictive rate-of-return guidelines
Growth	Include only practice-type site combinations that give high increase in growth	Include feasible practices even if vulnerable to more restrictive growth increase guidelines
Environment	Include only activities with low environmental impact	Include activities whose environmental impact is acceptable today
Multiple use	Include only activities whose impact on nontimber resources is low	Include activities whose impact on nontimber resources is acceptable today even if vulnerable to greater concern for nontimber values in the future
Manpower	Exclude activities that require high levels of Forest Service employees to supervise or enforce	Assume manpower will be available in the quantity required
Yields	Use low yield estimates	Use high estimates of yield that assume improvement in yield above today's technology
Budget	Assume only Knutson-Vandenberg funding level for future which is reasonably assured by existing law	Assume funding will be available to implement all activities the Forest Service thinks desirable
Land	Assume all roadless areas will be removed from the timber base	Assume all roadless areas will be retained in the timber base
Nontimber objectives	Assume all areas that have high nontimber values will have further reductions in timber yield	Assume all areas will be managed intensively for timber production
Other land uses	Assume continued loss of commercial forest land to roads, powerlines, reservoirs, etc.	Assume no further loss of commercial forest land

Table 10--*Some current assumptions in Forest Service timber management planning*

Item	Risk management assumption	Implicit risk management attitude compared with table 9
Treatment	Varies by region: include full stocking level control and genetics for which yields are mildly speculative but not fertilization for which yields are mildly speculative in some regions; few treatments in some regions	Mildly liberal to mildly conservative
Energy	No energy restrictions	Extremely liberal
Return on investment	Include practices that are feasible today but may not be in the future	Liberal
Growth	Include feasible practices even if they are vulnerable to more restrictive growth increase guidelines in the future	Liberal
Environment	Include activities even if their environmental impact is questioned today	Extremely liberal
Multiple use	Include activities even if their impact on nontimber resources is barely acceptable today	Liberal
Manpower	Consider manpower restrictions for first decades only	Mildly liberal
Yields	Use optimistic yield estimates with built-in reductions; degree of optimism varies by forest	Mildly conservative to liberal
Budget	Assume funding will be available as needed beyond first decade	Mildly liberal
Land	Assume all roadless areas not selected for wilderness study will be retained in timber base	Neutral to mildly liberal
Nontimber objectives	Assume many areas with high nontimber values will have timber yield reductions	Mildly conservative to mildly liberal
Other land uses	Assume no further loss of commercial forest land to roads, powerlines, reservoirs, etc.	Liberal

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Alternative Techniques for Analysis of Price Effects of Changes in National Forest Timber Flows:

A BACKGROUND REPORT

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ABSTRACT

Prices for forest products have emerged as a policy issue during recent debates over timber flow policies on National Forest lands. This background report provides perspective on the historical development of national concerns about the role of National Forest timber as it influences forest products prices. The economic framework for evaluating the price impacts of alternative timber flow policies is explained, and alternative methodologies for tracing these impacts through the U.S. economic system are described and compared.

Volatile price movements during the past decade and continued substitution of other materials for wood products have led to increased pressure on the Forest Service to recognize the price impacts of timber supply programs and to expand National Forest timber harvest to retard the long-term rise in relative prices of stumpage and other forest products.

Determination of the price effectiveness of alternative timber flow policies requires modeling both the structure and the price responsiveness of forest product markets. Alternative assumptions about market structure may range from treating supply and demand as separate entities to considering the interaction of supply and demand in spatially distinct markets. Price responsiveness may be considered in both supply and demand as well as price change relationships in various market levels. The key relationships modeled in any assessment of the price impacts of National Forest timber flow policies are linkages of timber harvest among ownerships and competing timber supply regions and linkages between end products and stumpage markets.

Approaches to the problem of modeling the price impacts of alternative timber flow policies were classified as one of the following: timber trend models, spatial models, single product, nonspatial econometric models, or quasi-spatial, multimarket econometric models. Of the various approaches considered, a quasi-spatial, multimarket econometric approach offered the most potential for displaying in a consistent manner both the price impacts of National Forest timber flow policies and the market forces which determine these impacts. The choice of an approach, however, must rest in part on the time available for analysis, the scope of the question to be answered, and the resources and analytical skills available.

KEYWORDS: Prices (market), market prices, forest product prices, supply/demand (forest products), forest products supply/demand, economic evaluation, policy (forest), National Forestry policy.

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INTRODUCTION

The Timber Harvest Scheduling Issues Study (USDA, Forest Service 1976b) displayed the impacts of alternative National Forest timber flows on selected consequences. One of the consequences selected for review was the price of timber products. A simulation model developed by Adams (1977) was used to display the impacts of variation in National Forest timber flows on softwood stumpage and softwood lumber and plywood prices. During the course of reviewing the price of timber products affected by National Forest timber flows, the study team considered the current role of National Forest timber in U.S. forest products markets and alternative approaches to modeling these markets.

The purposes of this report are to provide background information on the following for a more general audience:

1. Perspective on the historical development of national concerns over the role of National Forest timber in influencing forest products prices.
2. The economic relationships which determine the effectiveness of alternative National Forest timber flows in influencing prices.
3. Alternative methodologies and results of studies which have addressed the question of the influence of National Forest timber flows on forest products prices.
4. The implications of available information and the state of the art for assessing the effectiveness of National Forest timber flows in influencing forest products prices.

THE EMERGENCE OF PRICE AS A POLICY ISSUE

HISTORY

Current national concerns over the role of National Forest timber in determining forest products prices date from 1967 to 1969. During this period, softwood lumber prices increased by about one-third and the price of softwood plywood increased by 40 percent after declining for roughly 20 years. Passage of the Housing and Urban Development Act in 1968 focused attention on the effect of these price increases on the Nation's ability to meet the housing goals set forth in the Act. Price increases for end products were reflected in increased stumpage prices for National Forest timber. Industry members expressed fears that firms dependent on National Forest timber would be unable to compete with other producers. Market dislocations caused by the record housing years of 1972 and 1973 and the price controls from 1971-73 reinforced the concerns expressed during the 1967 to 1969 period.

The environmental movement and the current debate over energy policies add new dimensions to the impacts of rising forest products prices. As indicated by the "Timber Outlook" report (USDA Forest Service 1973), wood and wood fiber products have advantages over substitute materials in terms of environmental degradation and energy requirements. Increases in forest products prices relative to prices of substitutes set in motion a chain of events which decrease wood consumption in favor of substitute commodities.

Establishment of the National Forest System at the turn of the century was based on several rationales, but the effect of timber production on forest products prices was implicit only in the idea of preventing future timber "famines." The possibility of depletion of a national resource and "the cut and get out" practices of the time overrode concerns about low lumber prices.

Prior to World War II, management of National Forests was for the most part custodial. National Forest timber harvest was low compared with harvest from more accessible private lands. Rather than rising prices for forest products, the concern in the 1930's and early 1940's, as articulated by David T. Mason (1969), was how to increase timber prices as an incentive to increase management intensity on industry lands. Sustained yield and even flow on Forest Service lands were viewed as models to limit production and increase prices. Rising forest products prices following World War II ameliorated this concern.

In the 1950's and early 1960's, availability of private timber and increased allowable cuts on National Forests kept in the background concerns about the effect of National Forest timber on forest products markets. For lack of markets, the annual allowable cut on National Forest lands was not sold in many areas of the West.

PRICE AS A POLICY VARIABLE IN FOREST SERVICE PROGRAMS

The Forest Service has not explicitly tied timber flows to forest products prices. The annual allowable cut calculated for each National Forest is based on the physical characteristics of each forest, multiple use considerations, and the level of appropriations available for timber management activity. This approach to harvest scheduling does not recognize the potential for setting levels of Forest Service harvest so as to achieve, or at least move toward "desirable" price levels. The lack of price responsiveness in sales volumes has received criticism from several sources and alternative timber scheduling policies have been proposed (Newport 1973).

Although forest products prices do not enter into the procedure for calculating the annual allowable cut, price expectations do influence funding initiatives for Forest Service programs to intensify management on Forest Service and other lands and to increase utilization. Under current Forest Service program formulation, however, forest products price targets are not explicit criteria for judging the effect of alternative programs. Nor is there national consensus on what level of forest products prices would be "desirable" even if prices were explicitly recognized in setting National Forest timber flows. National direction on an appropriate relative price level for forest products would presumably be based in part on national materials policies. To date these policies have been too broad to provide guidelines for programs with specific price targets.

The effects of alternative Forest Service timber flows on forest products prices are only one of the consequences of changing the level of timber flows. Consistency of different timber flows with multiple use guidelines and other aspects of National Forest management would likely be balanced against the price impacts of these flows in any public decision on timber flow policy.

Although National Forest sales volume is not directly tied to forest products prices, the level of *harvest* does vary according to these prices because of timber sales procedures. With contract lengths of 3 to 5 years, timber sale purchasers have some discretion in setting harvest levels in response to market conditions. As a result, National Forest harvest has tended to move with conditions in lumber and wood products markets.

DETERMINANTS OF THE PRICE EFFECTIVENESS OF ALTERNATIVE TIMBER FLOWS

Within institutional constraints such as National Forest allowable cut policies, economic supply and demand forces determine the extent of change in forest products prices due to change in allowable cut levels. In order to identify the relationships between prices and National Forest harvest, we have to identify these market forces and either quantify them or make assumptions about their interactions. Since we are interested in the impact of changes in National Forest harvest on future prices, we also need to make assumptions about how market forces will operate in the future. The purposes of this section of the report are to present an overview of the economic system which determines the price effectiveness of different National Forest timber flows and to discuss different views of how to analyze this system.

ECONOMIC BASIS OF PRICE FORMATION

Figure 1 shows the conceptual model which is used to view the system that determines price formation in a free market economy. Quantity supplied

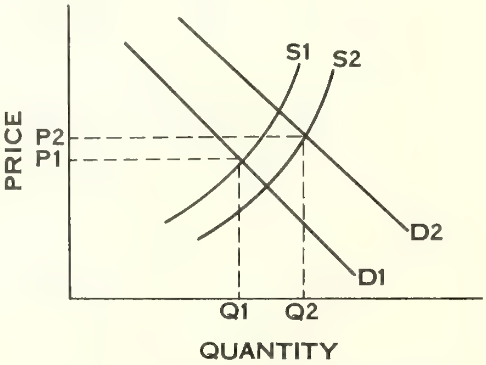

Figure 1.--Price effects of shifts in supply and demand curves.

increases as price increases, and quantity demanded decreases as price increases. We can view the initial situation as being portrayed by S_1, current supply, and D_1, current demand, which intersect to give an equilibrium price of P_1. The equilibrium price implies a stable price since at lower prices, demand exceeds supply and price is driven up to P_1. At higher prices, supply exceeds demand and price is driven down to P_1. Conceptually, a change in National Forest harvest shifts the supply schedule from S_1 to S_2. There may be a shift in demand such as from D_1 to D_2 concurrent with the shift in supply. The two curves intersect at P_2, the new equilibrium price.

The problem for the analyst in determining the price effectiveness of different National Forest timber flows is to describe the factors and relationships which underlie the supply and demand schedules portrayed in figure 1. In effect, the analyst is describing the behavior of producers and consumers in the economic system. For both producers and consumers, behavior depends on their capabilities and their objectives under alternative conditions.

Supply is defined as the volume of a commodity that producers put on the market at different prices. What quantities the producers could supply depends on the cost and availability of various factors of production such as labor processing and raw materials. Factor cost and availability change over time and these changes have the effect of shifting the level and responsiveness of supply to changes in prices. For example, the lumber producer may be constrained in the short run by capacity limits, availability of logs, availability of labor for mill crews, or other factors. In the longer run, logging equipment, processing capacity, and other factors tend to become variables rather than constraints and supply tends to become more responsive to changes in prices.

The supply of forest products is determined by the availability of stumpage. Available information on the price responsiveness of stumpage producers points to a difference between ownerships. Generally, privately owned timber is considered as being price responsive. This price responsiveness, however, may be constrained by the objectives of stumpage owners. For example, industrial stumpage owners may constrain their price responsiveness in the short run to maintain independence in the stumpage market in the long run. Stumpage owners must balance shortrun objectives with their view of the long run because once harvested stumpage cannot be replaced for several decades.

Demand is defined as the volume of a commodity that consumers could and would purchase at different prices. The demand conditions for the stumpage producers derive from the end product markets (e.g., lumber and plywood). In both the short and long run, price responsiveness of end product demand for stumpage depends on the cost and availability of labor and other factors of production used to process logs and transport processed products to consumers as well as the price responsiveness of consumers of end products. Processing sector demand also depends on the objectives of producers which have been discussed previously. Consumer demand depends, in both the short and long run, on the price of the commodity relative to prices of substitute and other commodities, consumer income, and the tastes and preferences of consumers. Consumer preferences are generally believed to be stable in the short run but vary over longer periods. In the long run, shifts in tastes and preferences and in relative prices change the price responsiveness of consumer demand to make demand generally more price responsive.

The level of demand at any point in time is determined by the complex of factors which shift the price-quantity demand schedule. Examples are the demand for wood in housing, and the price of steel studs compared with wood studs. The level of supply is determined by the cost and availability of labor and other factors of production. In the long run, technology also shifts the price-quantity supply schedule through refinements in techniques of production and other cost reducing innovations.

Although the characteristics of end product demand vary somewhat by region, the concepts of aggregate national lumber and plywood markets and regional stumpage markets have generally been accepted. These abstractions have been dictated by the availability of modeling techniques and data.

The price effectiveness of alternative National Forest timber flows in the West depends on interactions within the economic system. Forest products manufactured from this timber must compete in national markets with products from other regions such as the South and Canada. Within the West, changes in National Forest timber flows may affect stumpage markets. Stumpage supplies from National Forest and other sources interact to determine the volume of stumpage available at different prices. Stumpage demand in the West depends in part on national demand for processed products and the cost of supply factors other than stumpage such as labor. National Forest products prices act to shift regional stumpage demands, and regional stumpage demand and supply interact to determine regional stumpage prices. Interactions within regions and between regions and national markets change over time corresponding to changes in variables which shift supply and demand.

MEASUREMENTS OF PRICE RESPONSIVENESS

There are two relationships which are needed to determine the price effectiveness of alternative timber flows: (1) the degree of price responsiveness of the demand and supply relationships in the system, and (2) the relationship of end product price changes to stumpage price changes.

The elasticity[1] of supply or demand indicates the degree of price responsiveness of either relationship. Elasticities depend on percentage changes and are independent of the units used to measure quantity and price. Qualitatively, elasticity estimates are one of three types:

1. When a percentage change in price is accompanied by a larger percentage change in quantity, supply or demand is termed elastic.
2. When a percentage change in price results in an exactly compensating percentage change in quantity, the elasticity is equal to one (neither elastic nor inelastic).
3. When a percentage change in price evokes a smaller percentage change in quantity, supply or demand is termed inelastic.

One important difference between supply and demand elasticities is the negative sign associated with demand elasticities. When the price of a commodity is raised (all else held constant), less of it is demanded, thus the negative relationship. The reverse is true for the relationship between supply and price.

Available information for demand and supply elasticities for softwood lumber is shown in table 1. McKillop (1967) used a data base covering the years from 1929 to 1960 in arriving at an estimate of 3.2 for the elasticity of demand for softwood lumber. More recent studies (Adams 1974, Robinson 1974, Mills and Manthy 1974) used post-World War II data to estimate the demand elasticity to be less than 1. The "Timber Outlook" report, Marty (1973), and Josephson[2] assumed the demand elasticity to be -0.5 or less in their analyses.

Estimates of the elasticity of supply for softwood lumber range from 0.3[2] to 1.7 (McKillop 1967).

Among analysts, there is modest agreement that the demand elasticity is probably -0.5 or less in the short run with increasing elasticity in the long run. There is little agreement regarding the supply elasticity.

The linkage between the stumpage and end product markets must be considered in describing the behavior of producers and consumers in the economic system. Depending on the study approach this linkage may be explicitly considere within the model which describes the system or a linkage may be assumed. Because stumpage demand is derived from the demand for end products, both of these relationships are influenced in

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[1] Mathematically, the elasticity at a point is equal to

$$\varepsilon = \frac{(\Delta Q/Q)}{(\Delta P/P)},$$

where,

P is equal to price and

Q is equal to quantity.

[2] Josephson, H. R. 1975. Economic considerations in National Forest timber harvesting. 47 p. Internal Report on file at Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Table 1--*Available price elasticity estimates for softwood lumber*

Source	Elasticity[1] estimate		Comments
	Supply	Demand	
McKillop (1967)	1.7	-3.26	--
"Timber Outlook" (USDA Forest Service 1973)	--	-0.1 to -0.5	Value depends on length of run
Marty (1973)	0.6	-0.5	--
Mills and Manthy (1974)	1.2 to 1.6	Less than -0.5	--
Adams (1974)	--	-0.17	Douglas-fir lumber
Robinson (1974)	1.21	-0.87	Douglas-fir lumber
Josephson[2]	0.3	-0.5	Shortrun estimates

[1] Elasticity is equal to $\varepsilon = \frac{(\Delta Q/Q)}{(\Delta P/P)}$; where, P is equal to price and Q is equal to quantity.

[2] Josephson, H. R. 1975. Economic considerations in National Forest timber harvesting. 47 p. Internal report on file at Pac. Northwest For. and Range Exp. Stn., Portland, Oregon.

part by the same variables. This implies that there is a fairly constant ratio between the relative change in product prices and the relative change in stumpage prices.[3] The nature of the relationships between relative prices is that if stumpage prices rise while quantity processed and such other factors as prices of inputs used by producers remain fixed, the relative change in product prices will not exceed the relative change in stumpage prices. This means that η in footnote 3 is usually positive but less than one. This is confirmed by the observation that the stumpage elasticity is lower than the product elasticity (Mead 1966).

This is the underlying concept behind statements linking price changes in both markets (Haynes 1977). For example, Vaux (1970) applied the concept by assuming that demand elasticity in the stumpage market bears the same relation to demand elasticity in the lumber market as stumpage price does to total lumber price. Adams (1974) also alluded to this concept when he concluded that price shifts are largely "confined to the stumpage sector with successively smaller price changes at the log and secondary product level."

There is an inverse relationship between the elasticity of price transmission and the proportion of the change in end product prices which is passed through to stumpage prices. This linkage between the two markets is especially important in evaluating the consequences of policies designed to influence either stumpage or product markets.

ALTERNATIVE APPROACHES TO MODELING PRICE IMPACTS

To remain manageable, any model of the forest products or other sector of the economy must use assumptions to abstract from the general equilibrium nature of the U.S. economy. There are no absolute guides for judging the reasonableness of different approaches to modeling or the reasonableness of results portrayed by different models. Models may vary in their approaches because of time pressures, scope of the question to be answered, and the skills available. Judgments as to how well a model answers the questions of interest must rest on the reasonableness of the conceptual approach used to specify

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[3] This ratio is referred to as the elasticity of price transmission and is defined for a given product as:

$$\eta = \frac{(\Delta P^W/P^W)}{(\Delta P^S/P^S)};$$

where,

P^W = end product price and

P^S = stumpage price.

relationships in the model, how well the data fit these relationships, internal consistency of the model, and the reasonableness of results, given the model's assumptions.

Efforts to model behavior in markets for forest products have taken a number of approaches. This section describes the characteristics of existing studies in four major classes: timber trends models; single product, nonspatial econometric models; spatial models; and quasi-spatial, multimarket econometric models. For each approach, attention will focus on the attributes which influence its usefulness in examining the price impacts of alternative National Forest timber flows.

When interpreted for their usefulness in identifying the price impacts of alternative National Forest timber flows, all of the models have in common the treatment of these impacts as "endogenous" variables or variables to be explained by the model. For each model, the courses of price impacts through time are determined by interactions within the model and by the assumed courses of "exogenous" variables or variables not explained by the model. One of these exogenous variables is National Forest timber harvest.

TIMBER TRENDS MODEL

The basic concern in developing timber trends models is determining the difference between the potential demand and supply of a given class of wood products over time and at some prespecified price level or price trend. Generally, the class of products considered is quite broad, e.g., all softwood lumber or all hardwood timber, but this is not a necessary constraint of the method. Timber trends analysis has been applied most commonly to studies at the national level, though again this is not a necessary restriction. The best known examples of timber trends analyses are the series of post-World War II studies of the national timber situation conducted by the Forest Service: "Timber Resources for America's Future" (USDA Forest Service 1958), "Timber Trends in the United States" (USDA Forest Service 1965) and most recently "The Outlook for Timber in the United States" (USDA Forest Service 1973). Elements of timber trends analysis can also be found in "The South's Third Forest" (Wheeler 1970), "Report of the President's Advisory Panel on Timber and the Environment" (Seaton et al. 1973), the "Final Environmental Statement and Renewable Resource Program--1977 to 2000" (USDA Forest Service 1976a).

As exemplified in the "Timber Outlook" report, timber trends analysis may involve considerable detail in the development of both demand (or consumption) and supply (or production) estimates. Some specific price forecast is made as a basis for initial computations and subsequent comparisons. It has been customary to utilize an assumption of constant real prices for this purpose. Prospective future consumption by end product class is then forecast using this price base and a variety of techniques.

For the most part these latter methods involve consumption-income curves or slightly more complex variants of this approach in which adjustments are made in the relation between consumption and income (or other measures of activitiy in major markets) over the forecast period. If appropriate, projections are also developed at this stage for end product exports. It has been customary to treat these in a fairly qualitative manner in light of the uncertainty surrounding international trade policies. Consumption forecasts are then converted to log equivalents for comparison with supply forecasts.

Timber trends analysis procedures for supply are somewhat less clear. Ideally, the approach is to develop harvest forecasts by geographic region based on given price projections and (1) available information on the volume and growth of private forests, (2) some notions on the price responsiveness of private harvest, and (3) likely future allowable cut levels on public forest lands. Difficulties arise in this process through the need to consider any long-term sustained yield motives of private owners (which might constrain future cut-inventory relationships), potential management intensification on private lands, shifts in merchantability standards, and similar prospects. Since our understanding of the nature of these several processes and the factors which underlie them is highly imprecise, some qualitative, judgmental adjustments are required.

After all adjustments are made, regional forecasts are aggregated to national totals.

The final step involves comparison of aggregate supply and demand forecasts over the projection period. When supply forecasts fall below those for demand, price levels higher than those assumed as the basis for calculation are indicated. Supply greater than demand implies prices lower than the base forecast. This analysis, it is important to reiterate, is conducted at the national (or most aggregative) level. Timber trends analysis has generally not involved attempts to consistently gage deficiences or surpluses at disaggregate levels.

An extension of this basic approach was used by Marty (1973)--and in the "Timber Outlook" report--to examine outcomes under alternative price forecasts. In this variant, demand elasticities are developed for major categories of end products. For each new price forecast, demand is adjusted from the base projections using these elasticities. Supply projections are also adjusted using information on the price responsiveness of private cut; then supply-demand gaps are recalculated. The likelihood of realizing any given future price scenario can be estimated in this way. The price series of particular interest is that which equilibrates supply and demand over time.

Use of timber trends analysis to assess the price impacts of alternative Forest Service harvest schedules is straightforward. Levels of National Forest cut resulting from some hypothetical harvest policy are cumulated with private cut to obtain total timber supply under a specific price forecast. The demand-supply gap is computed and inferences made on the likely adjustments in price up or down from the initial forecast. As suggested above, several price forecasts could be analyzed until one is found which approximately eliminates the gap. A range of alternative harvest schedule policies might be examined in this way and their "zero gap" price forecasts compared.

There are some difficulties associated with this approach. First, since regional differences in the cost and production characteristics of forest products industries are not explicitly recognized, little can be said about the impacts of harvest policies which involve different regional allocations of Forest Service cut. In timber trends analysis, a given change in National Forest supply will have essentially the same price impacts whether it is concentrated in one region or spread uniformly across several regions. Second, timber trends analysis does not explicitly recognize any variability in the linkage between cut and inventory over time on private forest lands. In the usual approach, private harvest is adjusted for price level by moving up or down along hypothetical supply relations which otherwise remain fixed in each period of the analysis. But cut changes in one period in response to price should affect inventory and, hence, supply in all subsequent periods. We would expect private supply functions to shift, therefore, in some complex manner depending on the previous history of private cut. The assumption of a fixed supply curve may over or underestimate supply for any given period depending on the price forecast being examined. Finally, timber trends analysis does not treat questions of product transportation nor does it identify specific geographic demand areas. From the standpoint of analyzing alternative harvest flows, this leads to some uncertainty as to whether any specified increments in timber supply can actually be processed and traded in final product markets.

SPATIAL MODELS

Spatial models recognize the geographical distribution of consumers and producers. They differ from other modeling techniques discussed in this report in that the solution of spatial models usually involves some form of linear programing to allocate regional supplies to meet regional demands. Spatial models are well suited to forestry applications because they can represent the heterogeneous nature of forestry resources and processing facilities. These models demonstrate how the present levels of regional production, prices, and interregional trade might evolve through time under competitive conditions.

The forestry literature contains several examples of modeling portions of the forest economy in a spatial context. The earliest attempt was that of Holland and Judge (1963) who analyzed interregional competition in the lumber industry. Other examples include: Holley's (1970) spatial model of the plywood-lumber sector, Hallberg and Clemente's (1971) model of the northeast pulp and paper industry, and Davis, Lyons, and Burkhart's (1972) model of the southern Appalachian hardwood lumber-using industry. These analyses are similar in that they consider only one or two products and several regions.

Recent trends have been toward more comprehensive models featuring more detail in the regional and product specifications. For example, the Forestry Department of North Carolina State University and the U.S. Forest Service cooperatively developed a dynamic spatial model for simulating change in the softwood timber economy (Holley et al. 1975). The model was designed to take projections of quantity demanded by region for the major softwood products and to simulate industrial location and the regional cut-growth inventory balances of timber through the year 2000. This model offered no theoretical improvement over traditional methods of planning in that it ignored price interrelationships and took as given the consumption of forest products in future time periods. This approach has been expanded to include demand relationships as a base for allocating timber supplies to consumers.[4] The significance of incorporating demand equations into a spatial model is to allow price and quantity demanded in each region to fluctuate in response to changes in either available timber supplies or the level of total demand.

Spatial models offer a unique approach to handling questions regarding changes in National Forest timber flows which shift (outward) the stumpage supply only in some of the producing regions. Assuming capacity is available, greater production is possible resulting in lower regional and national prices. In spatial formulations these price changes are implied with the exception of Haynes' (see footnote 4) formulation where prices are treated explicitly. Spatial models simulate the changes in regional competitive advantage attributable to a change in National Forest timber flows. Spatial models tie the effectiveness of national programs to specific regions. The impact at the national level is then interpreted as an aggregation of regional changes.

SINGLE PRODUCT, NONSPATIAL ECONOMETRIC MODELS

In the period since World War II, major advances have been made in the field of nonexperimental statistics (the analysis of behavior under uncontrolled or uncontrollable external conditions). These methods have received wide attention in the social sciences and particularly in economics, where they are known as "econometric" methods.

In the forestry literature, econometric methods have been extensively employed in modeling forest products markets.[5] For the most part, however, existing models are fairly limited in scope. Specifically these models have usually considered the market for only a single end product (lumber has received the greatest attention), provide for only a unidirectional linkage between stumpage and end product markets, and give little or no attention to geographical variation in supply and demand conditions within the market of interest.

In a typical econometric model, attention is first given to the identification of the market to be studied, e.g., all softwood lumber, redwood lumber, softwood lumber from the Douglas-fir region, etc., and to the attributes of market behavior which are of specific concern, e.g., price, production, inventory, etc. A second step involves the generation of likely hypotheses to describe the relations among the attributes of interest within the market and the role of external or "exogenous" influences which shape market activity but are themselves largely independent of the market. These hypotheses are expressed in a mathematical form compatible with the statistical methods to be used in testing them. They arise, as a general rule, from both theoretical economic considerations and from operation of the market of interest. A third step, and one closely connected with the first two, is the collection of data which measure the market attributes and external variables. It is often found in this step that certain variables are not measured, are unmeasurable, or measured only with significant errors. In these instances, it may be necessary to revise candidate hypotheses, alter the focus of the analysis, and/or develop an alternative statistical procedure. A fourth step involves the application of statistical methods to the data to test the several hypotheses. Generally, this involves "fitting" of one or more equations (which embody the economic hypotheses) to the collected data. Should the tests fail to support the hypotheses, the process returns to the second step and attempts to determine both the reason for failure and the availability of alternative hypotheses. If the hypotheses are supported by the initial statistical analysis, a further set of so-called "validation" procedures may be employed to provide additional insight into the soundness of the hypotheses. This generally involves application of the models to some new, independently developed set or the use of some different statistical tests using the original data.

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[4] Haynes, Richard W. 1975. A dynamic, spatial equilibrium model of the softwood timber economy with demand equations specified. Ph.D. dissertation. 102 p., illus. On file at the School of For. Res., North Carolina State Univ., Raleigh, North Carolina.

[5] Examples include McKillop (1967), Simpson and Halter (1963), and Gregory (1960, 1965). A survey of more recent studies is given in Mills and Manthy (1974).

The value of model parameters (as determined in the fitting processes previously mentioned) is to provide a means for estimating the various supply and demand elasticities. By giving explicit representation to the several factors thought to influence supply and demand (or their analogs), econometric models also provide a structure for examining the quantitative extent as well as the qualitative nature of the shifts in supply, demand, and price discussed previously.

In general, econometric models of forest product markets have been of only limited utility for examining changes in levels of public timber harvest. The reasons are threefold. First, models have been restricted to a single market level, usually that of end products (lumber, plywood, etc.). Market impacts resulting from a public harvest shift begin at the stumpage level, move "upward" through log markets, and eventually affect end products. The process does not end here, however. Some feedback, in the form of changing end product prices and production levels, may also be expected which may moderate the initial changes at the stumpage level. Single product models have no means for considering these interactions.

Secondly, those econometric models which have considered the stumpage market and at least one higher market level have generally not distinguished between public and private harvest nor have they considered the relation between private harvest and private inventory. In the first instance, it has long been conjectured that changes in public cut would precipitate an offsetting shift in private harvest. Econometric models are of limited value in gaging the extent of this offset if they do not distinguish between types of owners in the stumpage market, or if, as in the Adams and Blackwell (1973) study, they consider only price relations at the stumpage level. Their usefulness is further limited if they ignore, as has been traditional, the stock or inventory of private timber. It is true that the nature of the connection between private timber inventory and private harvest is at best poorly understood. Still, some accounting for this critical variable would seem essential if in no other way but as a constraint on harvest. Indeed, it is conceivable that longrun projections with stock-independent models could produce physically unattainable forecasts of private timber harvest.

Third, most econometric models have ignored interregional competition in end product markets and related problems of differential transportation costs among supply regions. In timber trends analysis, it is customary to introduce at least a crude regional structure on the supply side, though this may not ultimately be related to the demand analysis. In econometric models, however, supply and demand relations are seldom disaggregated regionally. This presents difficulties for the analysis of changes in public harvest on several counts. The simplest of these problems relates to the treatment of stumpage markets. Although it may be reasonable to envision for the purposes of modeling a single aggregate national market for an end product, it is somewhat less realistic to do so for stumpage. There are significant regional disparities in stumpage prices in the United States.

Indeed such differentials may be an important stimulus to capacity migration in the forest industries. Regional differentials also exist in the cost structures of forest industries due to variation in wage rates, cost of nonlabor inputs (other than stumpage), age and condition of capital plant, and so on. These differences may be reflected in varying end product supply elasticities from region to region and hence in the potential impact of product price changes on regional industries. Further, the mix of private and public timber lands and timber inventories varies substantially across the United States. Taken together, these several considerations lead to the expectation that a given change in public timber harvest levels may have differential effects on producing regions. What is more, impacts on end product prices, consumption, and domestic production viewed nationally may also be quite different depending on the regional allocation of changes in cut.

Finally, in the absence of any direct consideration of the cost of transporting end products from producing to consuming regions, the projections of even those few models which are regionally disaggregated (e.g., Robinson 1974) must be questioned. For example, we would expect a decline in a region's stumpage and overall production costs caused by an increase in public harvest to lead to increased output in the region. This may not materialize, however, if the fall in production costs is insufficient to offset advantages held by competing regions due to lower transportation costs to final markets. In general, the class of econometric models discussed in this section are unable to consider this particular complexity.

QUASI-SPATIAL, MULTIMARKET ECONOMETRIC MODELS

As noted previously, some existing econometric models do give limited treatment to regional differences in industry supply characteristics and involve more than one product and market level (Adams and Blackwell 1973; Robinson 1974; Adams 1974, 1975). Adams (1977) attempted to develop a model involving a complete regional supply structure for several products and to explicitly link regional end product supplies to regional stumpage markets.

The model focuses on the structure of the stumpage, lumber, and plywood markets and utilizes econometric methods to obtain estimates of key parameters in this structure. Qualitatively, the approach is highly simplified and aggregative in that only the major aspects of structure within a given market are examined. All products within a market are assumed to be of homogeneous quality. No distinction is made, for example, among species or grades of lumber and plywood except as to their region of origin nor is stumpage distinguished by species, location, or quality within a given geographical region. Competition is assumed to prevail, and prices are set by the interaction of supply and demand forces. The model recognizes that cost structure in the production of lumber, plywood, and stumpage may vary from region to region but separate consuming regions are not identified nor are transportation costs from the several producing regions considered. Finally, the several relationships in the model describe behavior at only two specific points in the continuum of processing and conversion operations from standing timber to consumer. These are the supply and demand for timber for immediate harvest and the supply and demand for lumber and plywood at the mill level. Because of the structural characteristics of the model, it can be termed a quasi-spatial, multimarket econometric model.

The model is designed to estimate the longrun price impacts of changes in National Forest timber flows. In projections, no attempt is made to simulate the system's adjustments to cyclical market behavior. The model also abstracts from the problems of adjusting to changes indicated for the system such as movement of capacity from one region to another.

An outline of the model structure is given in figure 2. Four regions are recognized, corresponding to the four major softwood lumber producing areas: western coastal (WC), western pine (WP), southern pine (SO), and northern region.[6] The model involves behavioral

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[6] The western coastal region includes western Washington, western Oregon, and the California redwood area. The western pine region consists of all States west of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas (except for the western coastal region). The southern pine region consists of the 12 States from Virginia to Texas. The northern region includes the remaining States north of the southern pine region and east of the western pine region.

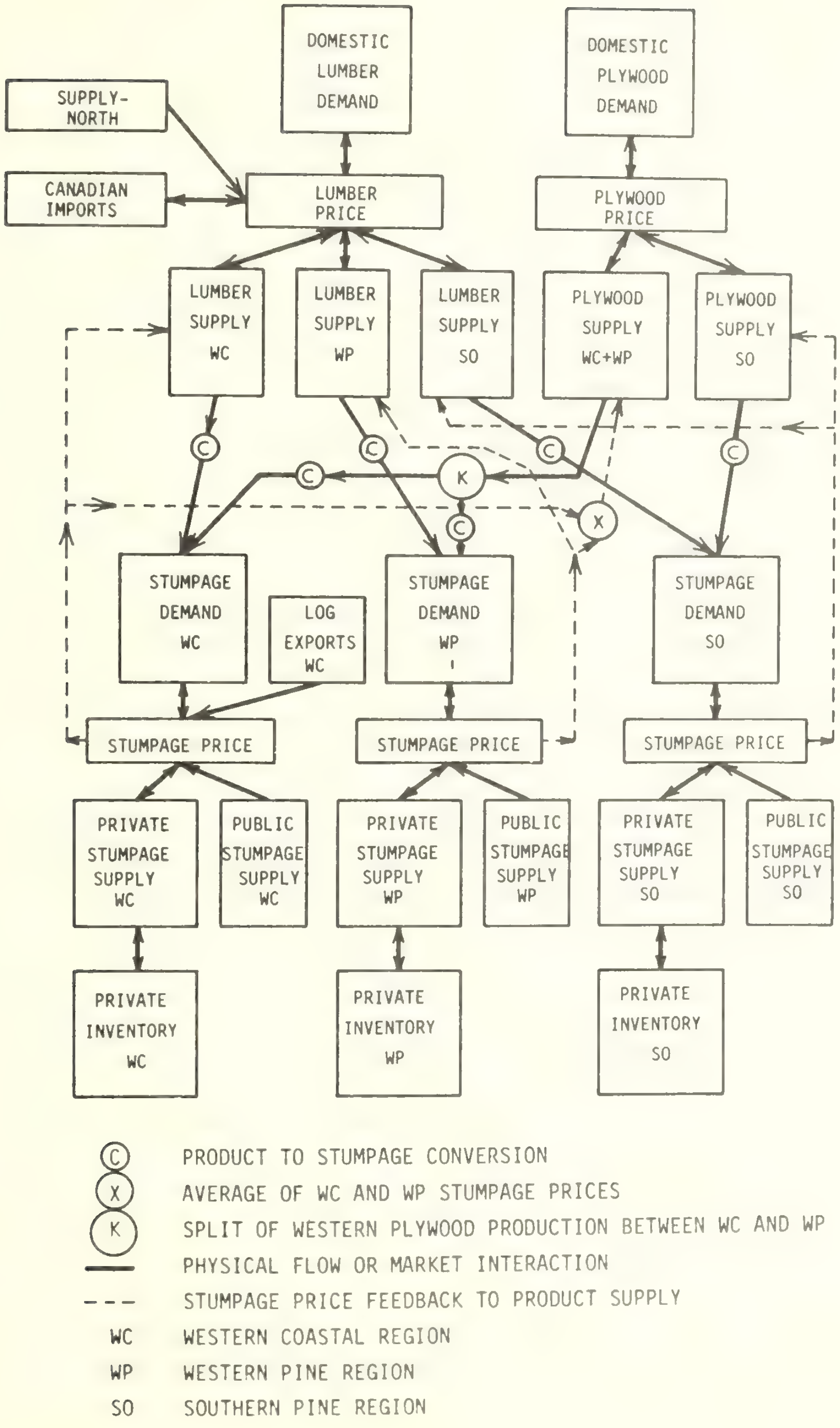

Figure 2.--Major elements and interactions of softwood timber market model.

equations for lumber, plywood, and stumpage markets. Pulpwood, pulp products, miscellaneous products (shakes, shingles, poles, piling, etc.), and fuelwood are treated as exogenous, and enter the model as additional demands on regional stumpage markets. Pulpwood is a minor component of total harvest in the West; fiber requirements are met in large part by use of plant residues. The situation is quite different in the eastern regions, with pulpwood demands exerting a strong force on regional stumpage market behavior. This source of stumpage demand is treated as exogenous, since it appears that stumpage price movements have only a limited impact on the production or prices of final pulp products. This is due in part to the structure of pulp products markets, the cost structure of pulp production, and to a lesser degree, to the relatively flexible wood-quality requirements of pulp production. Causal relations run strongly from product to stumpage sectors but only weakly in the opposite direction.

Miscellaneous products and fuelwood are sometimes of considerable local importance but are insignificant in terms of volume on a regional or national basis. Miscellaneous products prices are likely to be strongly linked to stumpage market activity, but those for fuelwood are not. Shifts in demand for either product have little influence on stumpage prices given the relatively large regions used in the present study.

Softwood production in the northern region has also been taken as exogenous. There is no softwood plywood production in this region, hence only lumber production enters the model. Federal forest land holdings are limited in the North and are only a minor source of softwood supplies. Softwood lumber output is small (less than 4 percent of the national total) and strongly oriented to local markets. National market changes undoubtedly influence production and prices in the region. Developments in the region, however, have only limited national impact.

The model assumes that regional supplies of both softwood lumber and plywood are homogeneous and enter uniform national markets. National softwood lumber and plywood prices are established and regional production determined by the relative position and elasticity of the several regional supply and import functions. Inventories of lumber and plywood are ignored. Each regional supply function is dependent in part on its respective regional stumpage price. Aggregate regional stumpage demand is determined directly by converting product supplies and export volumes to stumpage equivalents. Regional stumpage supply is the sum of a price and inventory elastic private component and an exogenous, completely inelastic public component. The levels of private cut determined by stumpage market interactions represent total product output from private timberlands. These are reduced by an estimate of the nongrowing-stock component and augmented by nonproduct removals from growing stock to obtain total removals from growing stock. A separate inventory sector uses the removals estimates to update private growing-stock inventories for use in subsequent projections.

COMPARISONS OF ALTERNATIVE APPROACHES

TECHNIQUES

A significant advantage of the quasi-spatial, multimarket econometric modeling approach used by Adams (1977) when compared with timber trends analysis is that prices are determined within the model and are consistent with production and consumption forecasts. In timber trends analysis, prices must be supplied to the model and appropriate adjustments made in volume forecasts. Some iterative approach must be attempted with timber trends analysis to find a price series which eliminates the "gap," i.e., equates production plus imports to domestic consumption plus exports. But this process would be essentially the same as the calculations involved in the Adams' model. Econometric models which focus solely on activities at the end product level suffer from a similar shortcoming. One cannot be certain that any projections of stumpage market activity (volumes or prices) which might enter these models are consistent with current and past projections of end product market activity.

The approach used by Adams (1977) provides substantial regional, product, and timber ownership detail on production and consumption flows not directly available in either timber trends analysis or single product econometric models. Further, the interregional, interproduct, and interowner substitutions or trade-offs observed over time in the quasi-spatial, multimarket econometric model arise from a consistent set of hypotheses regarding producer and consumer behavior. In timber trends analysis as employed in the "Timber Outlook," (USDA Forest Service 1973) for example, an elaborate regional inventory structure underlies the aggregate analysis. Regional harvest levels, however, are not directly connected to product market activity. Changes in forecast volumes of public harvest do not produce changes in private cut, in the composition of end-product output, nor in the relative market shares of different regions in response to any resultant product price changes. Indeed impacts on product and stumpage prices are unknown except the general direction of change. Consumption-oriented econometric models, with the exception of Robinson's (1974) model have generally not considered more than one region and hence have produced no information on these potential trade-offs.

The primary fault of the quasi-spatial, multimarket econometric model, as applied by Adams in terms of interregional comparisons, is its failure to consider transporation costs and the specific geographic foci of end product demand. Thus changes in the regional composition of product output predicted by the model might prove infeasible when considered in the light of the regional structure of demand and transport costs. The ability to consider such complexities is a major advantage of the spatial modeling approach.

Quasi-spatial, multimarket econometric models need forecasts of a large number of exogenous variables in order to make predictions of future price, consumption, and output levels. This is undoubtedly a burdensome task and strains our already limited ability to foresee future developments in the economic environment--particularly when projecting several decades into the future. It is important to recognize, however, that this problem is not really avoided by adopting alternative approaches. This is clearly the case for spatial models where information requirements may be even greater. It is also true in the use of timber trends analysis, at least as it has been traditionally applied in documents such as the "Timber Outlook" (USDA Forest Service 1973).

RESULTS

At least six studies have made longrun projections of equilibrium prices for lumber and plywood in the U.S. market. Projections from each study are shown in table 2. All prices

Table 2--*Projections of the lumber and plywood price index for selected studies (1970 = 100)*

Source	1970	1980	1990	2000	Rate of growth[1]
"Timber Outlook" (USDA Forest Service 1973)	[2]110	127	145	167	1.40
Marty (1973)	100	118	[3]	170	1.78
Mills and Manthy (1974)[4]	100	99	102	127	.80
McKillop (1974)	100	118	130	147	1.29
Josephson[5]	100	119	130	142	1.18
Adams (1977)	100	140	179	225	2.74

[1] Rate of change between 1970 and 2000 computed by the relationship
1 - t Pt/Po = i.

[2] This study used the level of 110 rather than 100 for the base year.

[3] Not reported.

[4] Softwood lumber index only.

[5] Josephson, H. R. 1975. Economic considerations in National Forest timber harvesting. 47 p. Internal report on file at the Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

were converted to 1970 dollars and price changes are in terms of real dollars. A combined index of lumber and plywood prices was used to make the estimates comparable.

Estimates for the rate of growth of real prices ranged from 0.8 (Mills and Manthy 1974) to 2.74 (Adams 1977). Differences in price projections cannot be attributed to any one factor. Differences in study approaches account for some of the variation in projections. The studies by Marty (1973), McKillop (1974), and Josephson (see footnote 2) are based in part on the timber trends methodology developed in the "Timber Outlook". The study by Mills and Manthy (1974) can be classified as a single product, nonspatial econometric model. The study by Adams (1977) is a quasi-spatial, multi-market econometric model. Even though the general approach may be similar for different studies, projections may still differ because of variations in assumptions about the interactions of supply and demand and because of different assumptions about the future course of supply and demand shifters.

The greater rate of growth in the Adams (1977) study reflects in part inclusion of 1971-1974 data which were not used in the other studies. In addition, the study approach used by Adams is different than the approaches used in the other five studies. Provision for interregional and international competition and for linkages between public and private harvest should result in higher prices compared with the other studies. For example, growth in supply in one region may be offset by the response of decreased supplies from other regions.

Available projections of equilibrium prices for stumpage are shown in table 3. For both the "Timber Outlook" and Josephson (see footnote 2) studies the approach used in projecting stumpage prices is similar. Both studies assumed that 75 percent of the increase in end product prices would be passed through to the stumpage market. The study by Adams (1977) makes no assumption about the linkage between the stumpage and end product markets. Prices in the stumpage and end product markets are assumed to reflect supply and demand conditions in each market. These conditions depend only in part on the linkage between the two markets.

The study by Adams (1977) projects a higher rate of growth in stumpage prices than do the other two studies which made price projections. As is the case for projections of end product

Table 3--*Projections of the stumpage price index for selected studies (1970 = 100)*

Source	1970	1980	1990	2000	Rate of growth
"Timber Outlook" (USDA Forest Service 1973)	100	134	175	221	2.68
Marty (1973)	1/	--	--	--	--
Mills and Manthy (1974)	2/	--	--	--	--
McKillop (1974)	1/	--	--	--	--
Josephson3/	100	128	145	163	1.64
Adams (1977)	100	181	277	377	4.52

1/ Both of these studies combined the stumpage and lumber markets, measuring prices in terms of end product prices and quantities in terms of sawtimber.

2/ Not reported.

3/ Josephson, H. R. 1975. Economic considerations in National Forest timber harvesting. 47 p. Internal report on file at Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

prices, differences in projections may vary according to study approaches, data bases, and assumptions about supply and demand shifters.

The data in table 4 are from the study by Adams (1977) and illustrate the sensitivity of regional harvest, stumpage prices, end product output, and national end product prices to a 25-percent increase in National Forest harvest in the West. The data show the extent of substitution between ownerships, regions, and nations. For example, increasing the National Forest cut initially reduces private harvests in the west coast region, but improves the West's share of U.S. lumber and plywood production at the expense of the South. Increased National Forest harvest reduces Canadian imports by the year 2000.

Table 4--*Selected harvest, price, and end product production levels for two National Forest (NF) timber flows in 1980, 1990, and 2000*[1]

Area and product	Present NF timber flow			Increased NF timber flow		
	Year			Year		
	1980	1990	2000	1980	1990	2000
	Harvest levels (million cubic feet)					
West coast region:[2]						
National Forest	700	700	700	875	875	875
Private	1,542	1,463	1,365	1,424	1,429	1,404
Western pine region:[2]						
National Forest	1,000	1,000	1,000	1,250	1,250	1,250
Private	676	716	844	649	697	828
Southern region:[2]						
National Forest	284	427	569	284	427	569
Private	4,021	5,189	6,757	3,885	4,987	6,516
	Price Levels (1970 = 100)					
Lumber and plywood	140	179	225	130	168	213
Stumpage:						
United States	181	277	377	162	244	339
West coast	367	559	778	300	470	673
Western pine	169	278	381	149	246	350
Southern	119	180	237	119	165	221
	Source of End Products, by Region (percent of U.S. total)					
Lumber:						
West coast	28	23	18	28	24	19
Western pine	24	22	22	27	25	24
Southern	20	26	32	18	23	29
Canada	27	27	26	26	27	25
Plywood:						
West coast	41	35	33	43	39	38
Western pine	17	16	16	18	17	16
Southern	43	51	53	40	46	47

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[1] Based on Adams (1977).

[2] The western coastal region includes western Washington, western Oregon, and the California redwood area. The western pine region consists of all States west of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas (except for the western coastal region). The southern pine region consists of the 12 States from Virginia to Texas. The northern region includes the remaining States north of the southern pine region and east of the western pine region.

IMPLICATIONS FOR ASSESSING THE PRICE EFFECTIVENESS OF DIFFERENT NATIONAL FOREST TIMBER FLOWS

Available information indicates that the Forest Service can influence forest products prices by varying National Forest timber flows in the West. Total timber supply changes by less than the change in National Forest timber flows. There is a net change in supply, however, and this affects prices.

Techniques are available to estimate the relationship between forest products prices and the level of National Forest timber flows. In addition, these techniques can be used to track at least some of the market forces which underlie this relationship. There is, apparently, professional consensus on how best to handle some of the problems of applying well-developed theories to the question of the price effectiveness of different National Forest timber flows. Definitive analyses, however, are not available for some of the relationships needed to use the state of the art to its fullest extent.

Analysis of the price effects of different National Forest timber flows necessarily involves projecting into the future. The future to a target year such as 2000 obviously cannot be predicted with certainty. The future course of demand and supply shifters such as the level and type of housing starts and technological changes will be major determinants of the price effectiveness of different National Forest timber flows.

Any technique used to project the price impacts of different National Forest timber flows must rely on assumptions as to how market forces will interact. Techniques vary in terms of their detail on these assumptions and then ability to test the internal consistency of the assumptions. The choice of a technique must continue to rest on the time available for analysis, the scope of the questions to be answered, and the resources and analytical skills available.

If and when there is national direction on the desired level of forest products prices, varying the level of National Forest timber flows could be considered as one means of achieving this goal. Current direction lacks specificity but implies that lower forest products prices are preferred because of goals related to housing, the environment, and other national concerns. Sophisticated analyses are not necessary to indicate the direction of change of forest products prices resulting from an increase in timber supply. The question of how much prices will change for different programs, however, must be answered if the effectiveness of these programs in reducing prices is to be judged.

In choosing among programs on the basis of price effects, the problem of analyses resting on assumptions may not be critical if these assumptions are consistent among programs. Price, however, is presumably just one of the criteria used to evaluate the merits of different programs. The decision framework would presumably weigh each program's effect on prices as compared with regional employment and other goals. In this framework the levels of price changes portrayed by the price impact analyses become critical as do the assumptions underlying each of the programs.

There are no prescribed guidelines for handling the problem of future program impacts being dependent on assumptions. One rationale is to test the sensitivity of impacts to the levels of different variables assumed in the analysis. This pinpoints the assumptions which decide the level of impacts but does not alleviate the problem of deciding what level or what characteristics to assign to these assumptions.

If alternative programs are to be judged on their effectiveness in achieving price and other goals such as regional development or industry stability, there seems little choice but to move toward more detailed analyses which are internally consistent and which portray the market forces that determine the effectiveness of the program.

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U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

Abstract

This report provides information on the biological relationships between the spruce beetle and white spruce in Alaska. It is directed to forest managers, entomologists, and the general public who are concerned with managing the forest environment. The report presents problems associated with the spruce beetle and characteristics for identifying problem areas, and describes methods for preventing or suppressing beetle problems through proper forest management techniques.

KEYWORDS: Insect damage (-forest, insect damage control (forest), insect populations, management (forest), spruce beetle, *Dendroctonus rufipennis*, white spruce, *Picea glauca*, Alaska.

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Introduction

The purpose of this report is to familiarize the reader with the biology of the spruce beetle, the tree injury it causes, and various forest practices employed to reduce tree mortality and to salvage some benefits when trees are killed.

White spruce (*Picea glauca* (Moench) Voss) forests are subject to mortality from a variety of causes. Fires, windstorms, disease outbreaks, and insect infestations are some important events causing tree mortality. Of all the insects affecting white spruce, the spruce beetle (*Dendroctonus rufipennis* Kby.) has caused the most extensive mortality in Alaska's white spruce forests.

Periodically, spruce beetle populations increase rapidly; one such outbreak caused about 81 000 hectares (200,000 acres) of tree mortality along the Copper and Chitina Rivers from approximately 1920 to 1930 (Downing 1957). Factors contributing to that outbreak are not known. In the early 1960's, spruce beetle populations on the Kenai Peninsula had built up in white spruce and closely related Lutz spruce (*P. lutzii* Little) (Downing 1961). Localized beetle activity increased; and by 1971, infestations covered about 105 300 hectares (260,000 acres), with losses estimated at a billion board feet (Curtis and Swanson 1972). In 1972, an additional outbreak was reported near Tyonek (fig. 1) (Baker and Curtis 1972). By 1975, the year of its decline, the outbreak had extended over a total of 115 130 hectares (284,370 acres[1]).

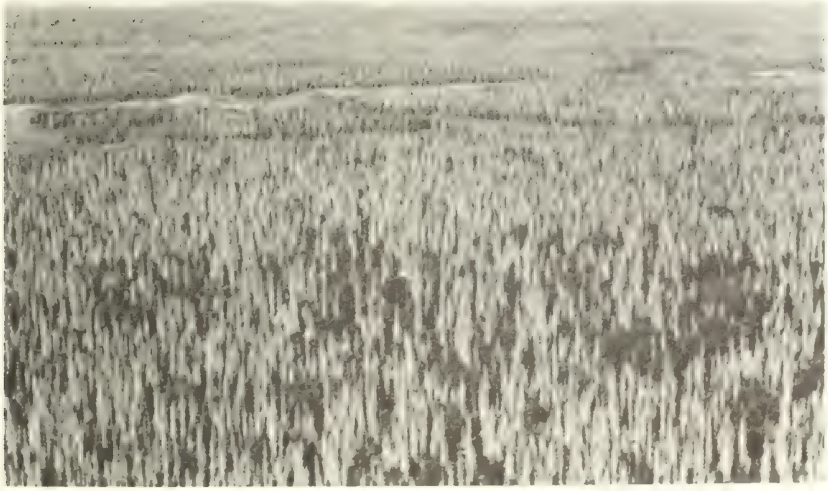

Figure 1.--White spruce-paper birch stand near Tyonek, Alaska. Light gray trees are spruce killed by spruce beetles.

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[1] Data on file with Forest Insect and Disease Management, Forest Service, U.S. Department of Agriculture, Juneau, Alaska.

Beetle Description and Life Cycle

DESCRIPTION OF BEETLE LIFE STAGES

The adult spruce beetle is dark brown to nearly black with reddish-brown wing covers (fig. 2) and is 4-7 mm (0.16-0.28 inch) long and 3 mm (0.12 inch) wide (Schmid and Beckwith 1975).

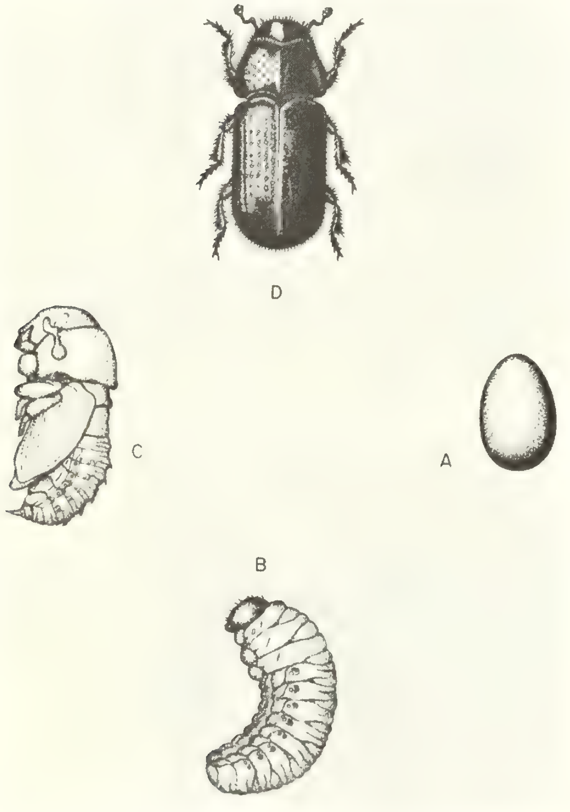

Figure 2.--Life stages of spruce beetle (A) egg, (B) larva, (C) pupa, and (D) adult.

Callow adults (those recently developed) range from pale yellowish to medium brown. Eggs are pearly white, oblong, and 0.75-1.0 mm (0.03-0.04 inch) long. Larvae are stout, cylindrical, legless, and wrinkled with a pale tan head and creamy white body. A mature larva is 6-7 mm (0.24-0.28 inch) long (Grant and Cottrell 1968). Pupae are creamy white and become tan near maturity. They are 6 mm (0.24 inch) long with the legs, wings, and antennae fully visible.

SEASONAL HISTORY AND DEVELOPMENT

The development of the spruce beetle depends on climatic conditions, geographic area, and elevation. In most of Alaska, the spruce beetle has a 2-year life cycle in white spruce. Beetles overwinter mostly as adults or larvae in northern latitudes (Fairbanks area), with adults occupying pupal sites in the bark of the trunk or below snowline in the bark of the roots or base of infested trees. South of the Alaska Range (Anchorage area), an equal number of larvae can be found overwintering under the bark of the trunks of standing trees.

North of the Alaska Range, overwintering callow adults mature and emerge from mid-May through July; whereas in south-central Alaska, adults emerge from early June through mid-July (Beckwith 1972). The newly emerged adults attack fresh host material such as windfall, freshly cut logs or injured trees, slash, and even standing, healthy trees. Overwintering larvae mature into adults during the spring months and emerge and attack in late summer. Some adults that make their initial attack in late summer may overwinter and make a second attack the following spring (Grant and Cottrell 1968).

Upon finding a suitable host, the female beetle bores through the bark into the phloem area, i.e., the area between the outer bark and the wood, and starts to construct an egg gallery, scoring the xylem (wood) slightly in the process (fig. 3). The male then enters the gallery, probably attracted there by chemical odors produced by the host tree and the female beetle; and there mating takes place. The egg gallery is constructed parallel to the wood grain and usually upward from the entrance hole in standing trees (fig. 4). The galleries are slightly wider than the beetle and are 6-30 cm (2.4-12 inches) long (Schmid and Beckwith 1975). Eggs are laid in groups on either side of the egg gallery.

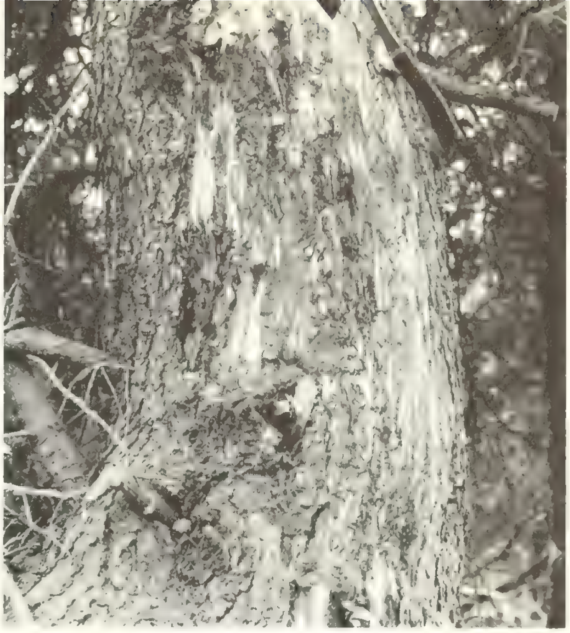

Figure 3.--Spruce tree with section of bark removed to show beetle galleries scored in xylem (wood) of tree trunk.

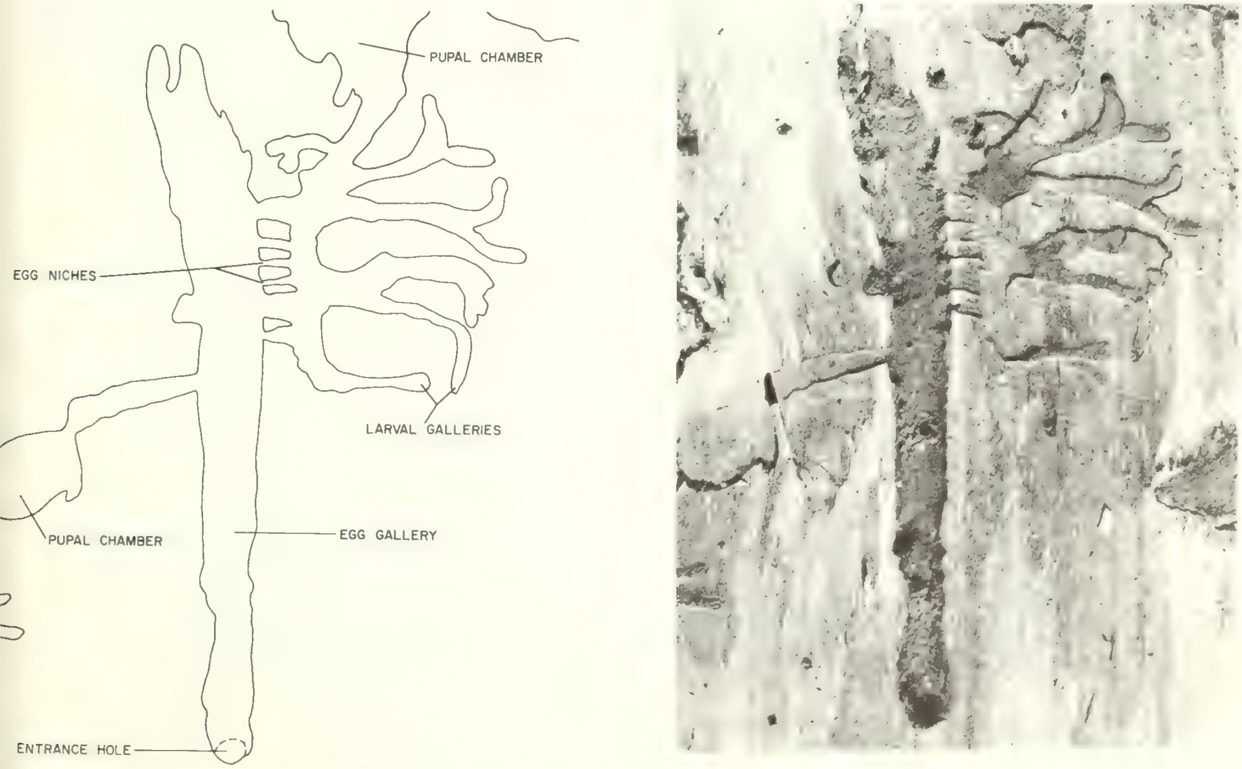

Figure 4.--Spruce beetle egg gallery in phloem of white spruce tree (parallel to grain). Galleries across grain are made by newly hatched larvae.

The number of eggs laid varies from 4 to 14 per cm (0.4 inch) of gallery. Parent beetles that survive may then re-emerge, attack, and establish a second brood or overwinter in the original host tree and re-emerge and attack the following spring. The eggs from early summer-emerging beetles usually hatch in 3-4 weeks, and develop into mature larvae which overwinter and develop into pupae and adults the following spring.

Newly hatched larvae bore at right angle from the longitudinal egg gallery and feed in clusters in the phloem. Larvae begin to form individual feedling galleries when they are about one-third grown. In south-central Alaska, many larvae develop into pupae and adults in the late summer; and the insect may overwinter as callow and/or parent adults. Before the larvae are fully mature, they excavate a shallow cell in which they form into pupae (fig. 5); however, some of the mature larvae bore into the inner bark where they excavate pupal cells.

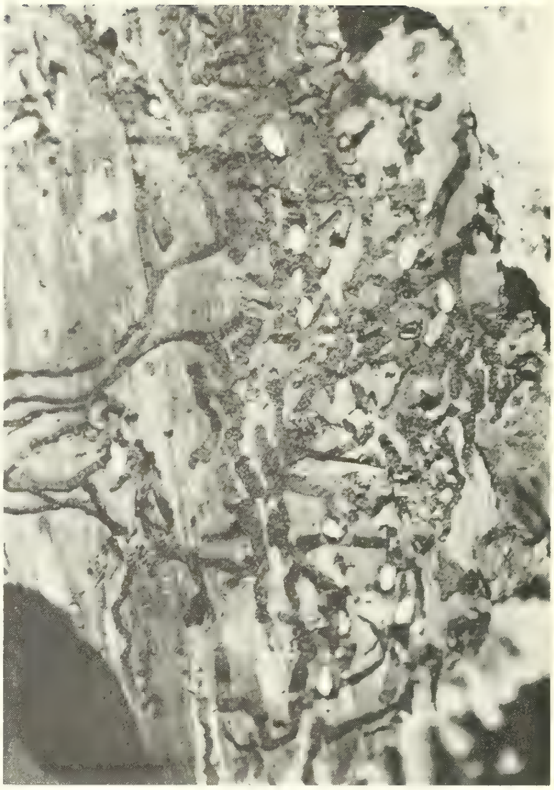

Figure 5.--Spruce beetle pupae in pupal chambers at end of larval galleries.

Beetle Damage and Tree Losses

TYPES OF SPRUCE MATERIAL INFESTED

The previously mentioned large outbreaks have occurred in an area of Alaska lying between the moisture-laden maritime zone, where white spruce yields to Sitka spruce (*P. sitchensis* (Bong.) (Carr.), and the continental zone of the interior, where the spruce beetle is common but where extensive outbreaks had not been recorded as of 1976. These outbreaks also occurred in spruce forests containing many large diameter trees; and recent outbreaks in the Cook Inlet basin were associated with warm, dry summers in 1968 and 1969 and accumulations of spruce debris resulting from forest clearing (Crosby and Curtis 1970). Spruce slash, cull logs, stumps, or windthrown trees are highly productive breeding sites for the insect (Massey and Wygant 1954, Dyer and Taylor 1971) (fig. 6). When populations increase and sufficient down material is no longer available to absorb the population, beetles

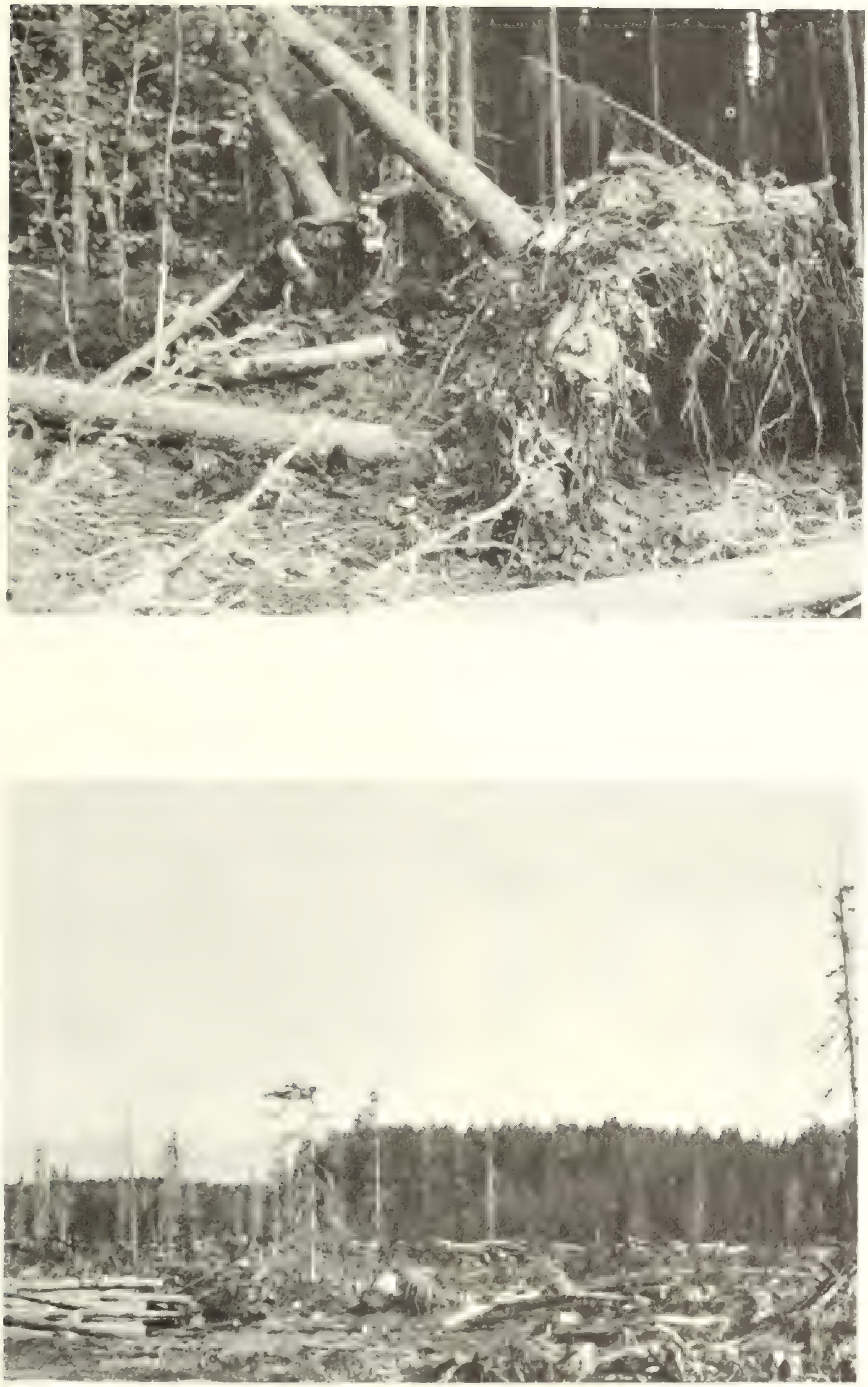

Figure 6.--Windthrown trees and logging slash are highly susceptible breeding sites for spruce beetles.

infest nearby living trees, particularly in mature stands and during warm, dry summers (Schmid and Beckwith 1975).

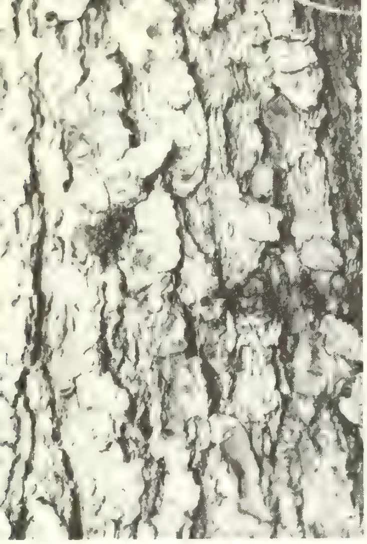

Figure 7.--Boring dust excavated from the bark and phloem by adult beetles.

CHARACTERISTICS OF BEETLE-INFESTED TREES

The first indication of beetle attack is reddish-brown boring dust deposited at the beetles' entrance holes, in bark crevices, and on the ground around the trunk of the infested tree (fig. 7). A close examination of the tree to detect these indicators is necessary, particularly in the early stages of attack or on cloudy days when light intensity is reduced. Boring dust produced by carpenter ants and wood boring beetles can be distinguished from that of the spruce beetle by its light yellowish color (fig. 8). Globules of resin (pitch tubes) located on the tree trunk are additional evidence of beetle attack (fig. 9).

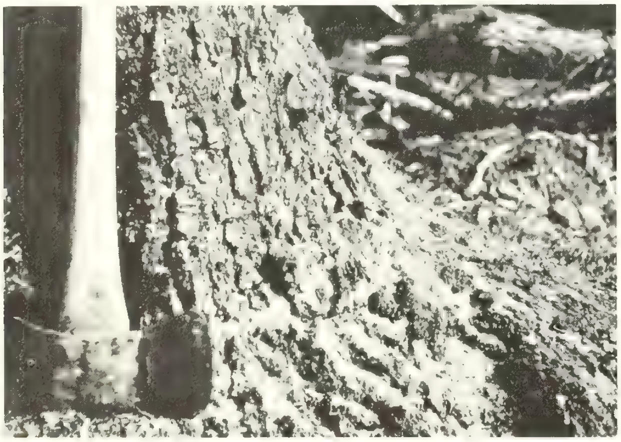

Figure 8.--Boring dust produced by carpenter ants in the trunk of a spruce tree.

Experience with spruce beetles in Engelmann spruce (*Picea engelmannii* Parry) indicates that infestation intensity depends on tree size, age, and basal area, percentage of spruce in the canopy, and physiographic location (exposure and elevation of site) (Schmid and Frye 1976). Some trees overcome beetle attack by exuding a heavy flow of resin which fills the beetle galleries and entrance holes and traps the beetles. The success of such trees to overcome attack depends on the number of beetles attacking the tree, the rate of attack, and the vigor of the tree. Trees that repel beetles contain resin tubes that are usually whitish in color; but if beetles continue boring, the resin tubes become

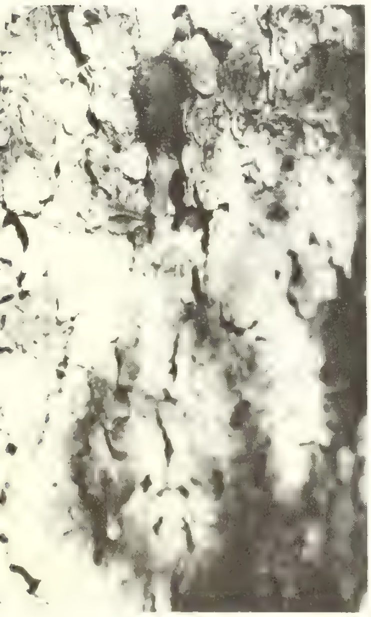

Figure 9.--Resin tube is external evidence that beetles are or have been attacking the tree.

mixed with boring dust and frass (beetle feces) and appear reddish-brown. Less vigorous trees or trees attacked late in the summer often produce few or no resin tubes when under attack; however resin tubes and resin flow, in general, are poor criteria for distinguishing beetle attack because uninfested trees sometimes exhibit resin flow on the bark due to abnormal physiological conditions or sapsucker damage.

After the tree has been infested and the phloem girdled by beetle galleries, the needles turn yellowish-green (begin to fade) and may remain that color throughout the winter following attack of the previous summer. Within 2 years after the initial attack, needles may fall (fig. 10) and the trees frequently appear reddish-brown due to the color of exposed twigs. Trees with reddish-brown crowns usually no longer contain spruce beetles. Sometimes trees may be infested with beetles on only one side and will appear faded green or even normal in color. This is known as a "strip attack" because unsuccessful attacks are sustained on only one side of the tree, usually on less than one-half of the circumference. The tree retains a continuous strip of live cambium from the top down to the roots. These trees do not appear discolored but have the other external symptoms of beetle attack such as boring dust and, sometimes, resin tubes on the infested portion. The degree of discoloration of infested trees may be associated with the amount of soil moisture prior to and during beetle attack, humidity, exposure, site, elevation, tree vigor, root disease, or intensity and success of attack.

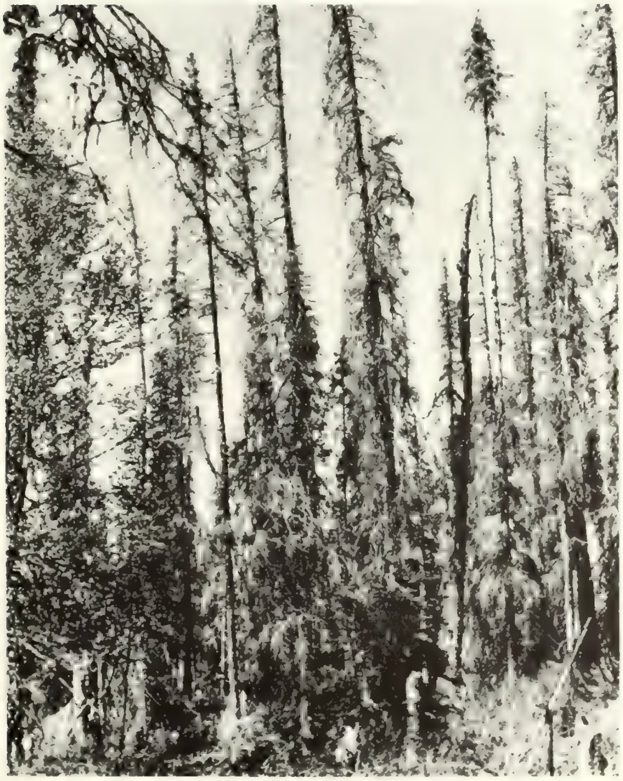

Figure 10.--Spruce trees killed by beetles appear lighter in color than healthy trees.

Discolored or faded trees are commonly found that have not been attacked by beetles. The causes of this particular discoloration could be attributed to several factors: lack of proper nutrients, inadequate moisture, site condition, diseases, air pollutants, or some unknown physiological malfunction of the tree.

Beetle-infested trees are prime feeding sites for woodpeckers, and bark removed by the pecking activity can be found scattered around the base of most infested trees (fig. 11).

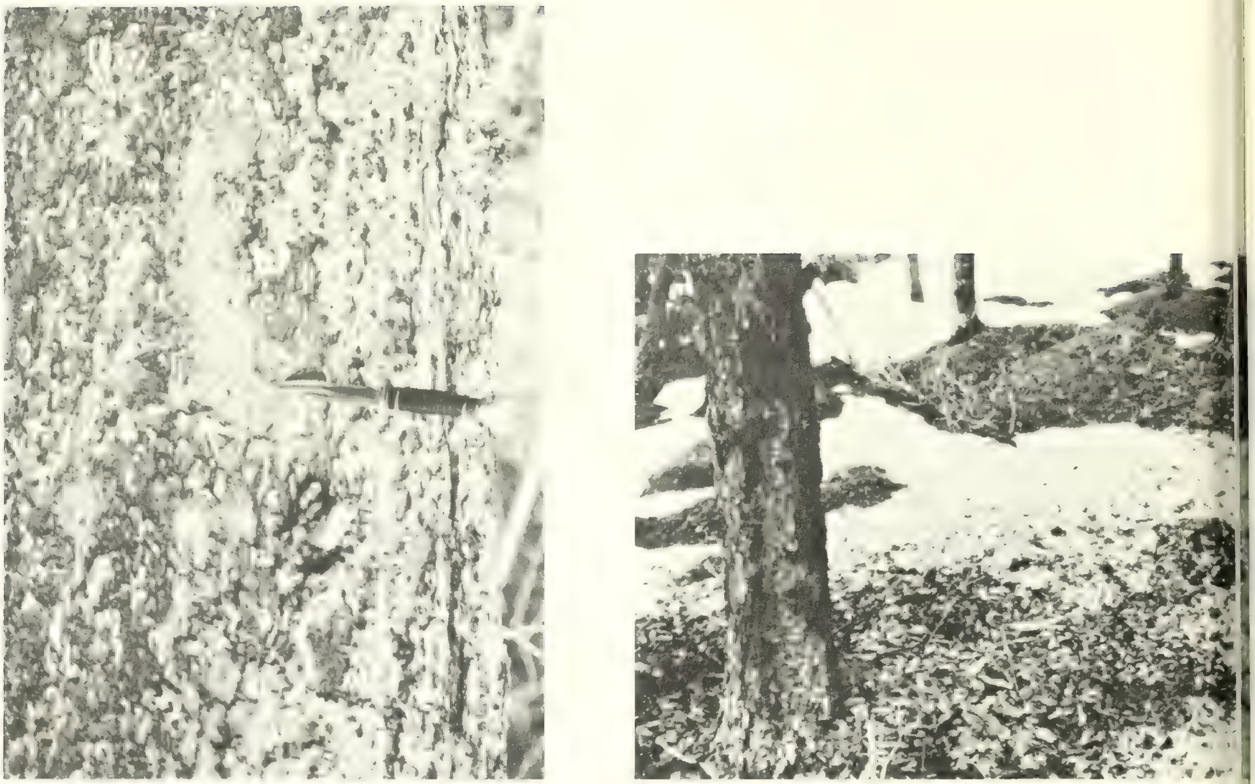

Figure 11.--Beetle-infested white spruce trees showing patches of bark removed by woodpeckers in search of beetles (left) and bark debris caused by woodpecker activity (right).

BEETLE IMPACT ON SPRUCE STANDS

Increases in spruce beetle populations and subsequent losses to white spruce stands depend on: (1) climatic and seasonal weather conditions, (2) physiographic location of spruce stands, (3) stand composition, (4) natural mortality factors of the beetle, and (5) disturbance of the spruce stand which results in an abundance of spruce debris. Combinations of the above factors result in unusually high tree losses.

Large, mature white spruce stands are highly susceptible to spruce beetle attack (Baker and Kemperman 1974), and such stands are typical of interior and south-central Alaska (fig. 12). High populations of the spruce beetle are quite capable of modifying stand age class and species composition as reported by Baker and Kemperman (1974) for south-central Alaska. They examined a white spruce-paper birch forest that consisted of 77 percent white spruce and 22 percent paper birch prior to

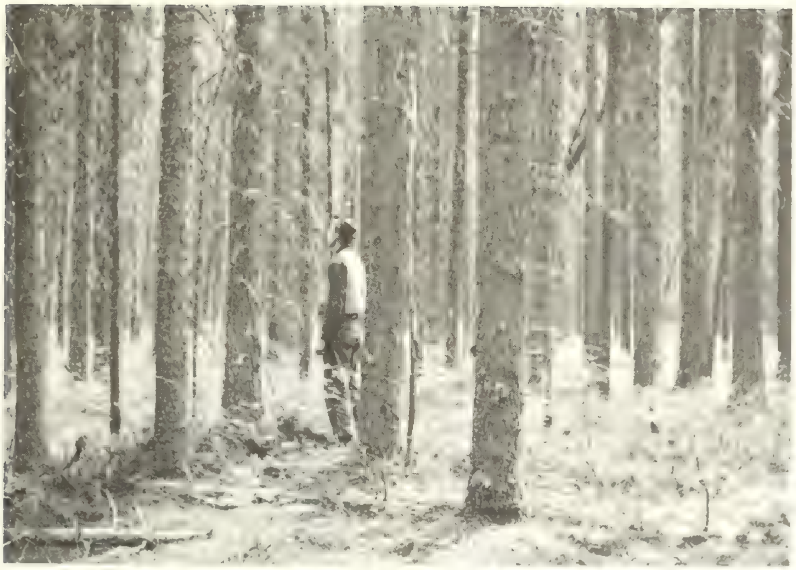

Figure 12.--Typical mature white spruce stand in interior Alaska.

infestation by spruce beetles. At the end of the outbreak, 65 percent of the spruce 12.7-cm (5-inch) d.b.h.[2] and larger had been killed. The incidence of tree mortality was directly proportional to tree size class (fig. 13). The average age of surviving dominant and codominant spruce was 142 years, but ages ranged from 75 to over 230 years. Spruce regeneration was sparse in the infested stand. There was an average of 11 spruce saplings[3] per hectare (28 per acre); the range was 0-77 per hectare (0-192 per acre) on sample plots. Spruce seedlings[4] ranged from 0 to 680 per hectare (0-1,700 per acre) on sample plots. Deciduous competition to spruce includes birch, rusty menziesia, currant, ferns, and other species. This type of residual vegetation can make future stand composition of spruce uncertain.

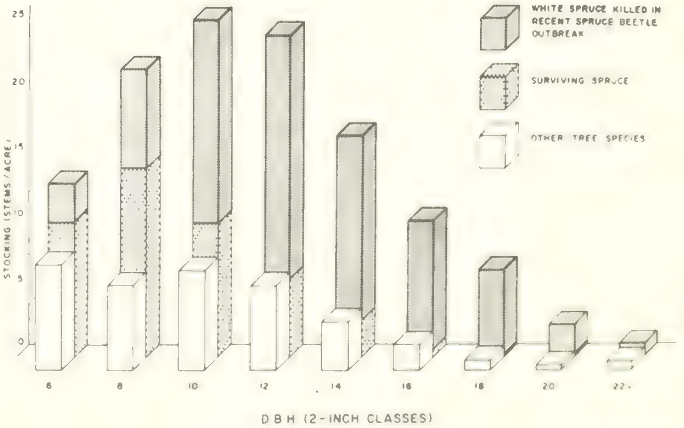

Figure 13.--Effect of beetle-caused mortality on stand composition. Other species consist of 22.0-percent paper birch and 1.2-percent balsam poplar and mountain hemlock.

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[2] Diameter breast height.

[3] Saplings, 2.5- to 12.7-cm (1- to 5-inch) d.b.h.

[4] Seedlings, 2.5-cm (1 inch) to less than 1.3 m (4.5 feet) in height.

It is important to realize that the previously mentioned losses are unusually high and that the surviving spruce components of other residual stands may be considerably higher. The above is an example of what can occur rather than what necessarily will occur. However, it is not uncommon for a spruce beetle outbreak to continue until most large spruce have been killed. A forest with an abundance of large, mature white spruce is prerequisite to beetle outbreaks if combinations of the forementioned factors are present. Such a stand remains susceptible to the beetle unless forest composition is altered by fire, harvest, extensive windthrow, or the beetles themselves.

Once mortality is quantified, various economic yardsticks can be used to determine actual monetary losses or, in some cases, benefits. An example of a loss is timber inventory destroyed; a benefit would be an increase in browse plants where moose habitat management is a high priority, or the conversion of a conifer forest into a more desirable hardwood forest.

Forest Management

Management of Alaska's white spruce forests to reduce losses from spruce beetles should involve the following actions: (1) specific preventive forest practices, (2) forest stand manipulation, (3) salvage logging to prevent economic losses in infested areas, and (4) beetle population management.

PREVENTIVE PRACTICES

One means of preventing spruce beetle outbreaks is to avoid creating forest conditions which are conducive to the buildup of beetle populations (fig. 14). Preventing the accumulation of felled spruce material greater than 15.2-cm (6-inch) diameter (fig. 15) will

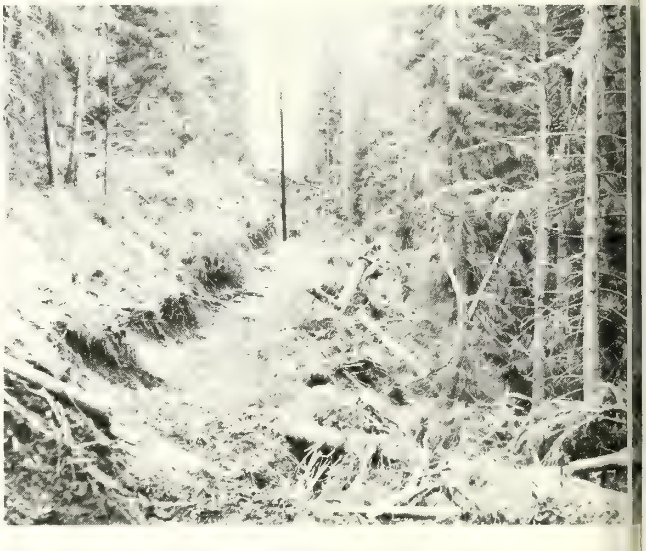

Figure 14.--Forest clearing without proper slash disposal.

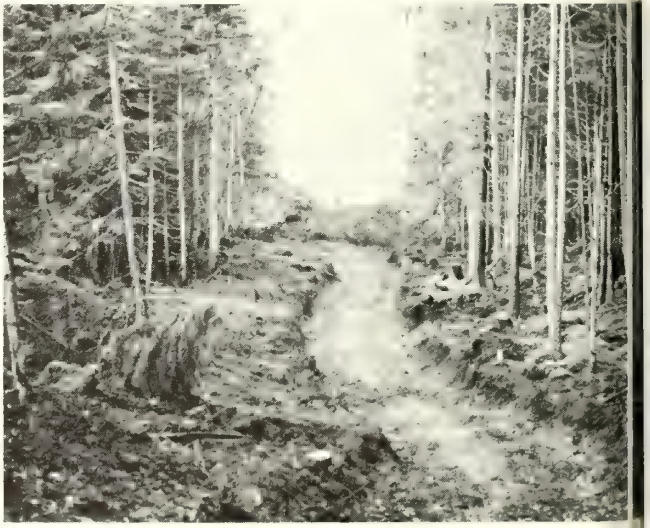

Figure 15.--Forest clearing following slash disposal by burning.

preclude beetles from multiplying in down material and subsequently infesting healthy trees. Windstorms can cause the same result, although they occur infrequently and their occurrence is usually beyond man's control.

Spruce debris over 15.2-cm (6-inch) diameter, from man-caused activities in the forest, should be properly handled before beetle emergence. Proper handling can consist of utilization, burning, burying, or some other method that destroys the developing insects, disrupts their development, or denies their access to host material. Avoid damaging tree trunks and root systems so beetles will not be attracted to these weakened trees. Care should be taken to avoid (1) scarring trunks with equipment, (2) severing roots in road and drainage activities, (3) altering drainage patterns around root systems by cut and fill operations, and (4) severely compacting soil.

FOREST STAND MANIPULATION

Forest stand structure and species composition can be variously altered to reduce susceptibility to beetle outbreaks. The key is to maintain a stand that does not consist of numerous large, overmature spruce. Thinning, shelterwood harvesting, clearcutting, fire, and even the beetle itself can create a forest with fewer large spruce than would otherwise exist. Clearcuts provide maximum sunlight for felled logs, and beetles cannot survive high temperatures generated by direct sunlight. On the other hand, clearcutting large areas can create forest edges that are highly susceptible to blowdown. Size and location of timber sale are important in creating spruce stands that can withstand high winds.

Long-term timber management goals should emphasize harvesting older stands and establishing a rotation age of 100 years. Simultaneous outbreaks over large areas, as in the Tyonek and Kenai outbreaks, can be prevented by planning a mosaic of forests of different age classes. Young stands of spruce are less susceptible to beetle infestation than are mature stands, and mixed stands of spruce and hardwoods will not suffer the losses that pure spruce stands will suffer given trees of comparable diameter size.

In some situations where a localized yet troublesome population of spruce beetles is active, trees can be felled and purposely left temporarily to attract and concentrate beetles (Schmid and Beckwith 1975). After beetles have entered downed trees or logs, they can be destroyed through wood utilization, burning, or chemical application.

SANITATION AND SALVAGE CUTTING

Sanitation cutting involves the felling of beetle-infested trees in a stand and destruction of the beetles prior to their emergence. This method can be an effective means of preventing the spread of newly developed and fairly localized infestations in Alaska's white spruce stands. The success of sanitation cutting depends on periodic surveys throughout the summer in order to detect beetle brood trees. This method is somewhat costly because helicopters may be required to transport suppression crews to remote beetle-infested areas. Infested trees that are felled can be utilized, if accessible, or burned in isolated areas where other methods of destroying the beetle population are impractical.

Salvage utilization is not a method for reducing beetle populations but is used primarily to reduce losses inflicted by large beetle outbreaks. Beetle-killed trees yield good fiber for a considerable number of years. Although the potential for use as dimension lumber may begin to decline soon after a tree is infested, the potential for pulp is far more lasting. Tree deterioration and pulping data for south-central Alaska's white spruce have shown that beetle-killed spruce dead for 50 years produced kraft pulps of premium quality in strength and brightness.[5/]

BEETLE POPULATION MANAGEMENT

The following discussion is concerned primarily with methods and techniques that deal directly with the insect.

Preventing the occurrence of an insect problem is obviously better than suppressing one after populations have increased. Prevention of beetle population increases by biological means is the most desirable approach but presently is limited to a few proven techniques. Most are still in the developmental stages.

One such technique is the use of behavioral chemicals such as aggregation attractants and antiattractants. Attractants are used to trap beetles which aggregate to the source whereas antiattractants disrupt normal aggregation and mating patterns and prevent buildup of beetle populations. The use of antiattractants to suppress initial outbreaks of spruce beetle activity in Alaska has shown promise (Furniss et al. 1976).

Future developments and refinements in the use of behavioral chemicals to suppress beetle activity will provide the land manager with additional prevention and suppression techniques; however, the best beetle control is prevention through proper forest management.

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Fairbanks, Alaska
Juneau, Alaska
Bend, Oregon
Corvallis, Oregon
La Grande, Oregon
Portland, Oregon
Olympia, Washington
Seattle, Washington
Wenatchee, Washington

Mailing address: Pacific Northwest Forest and Range
Experiment Station
P.O. Box 3141
Portland, Oregon 97208

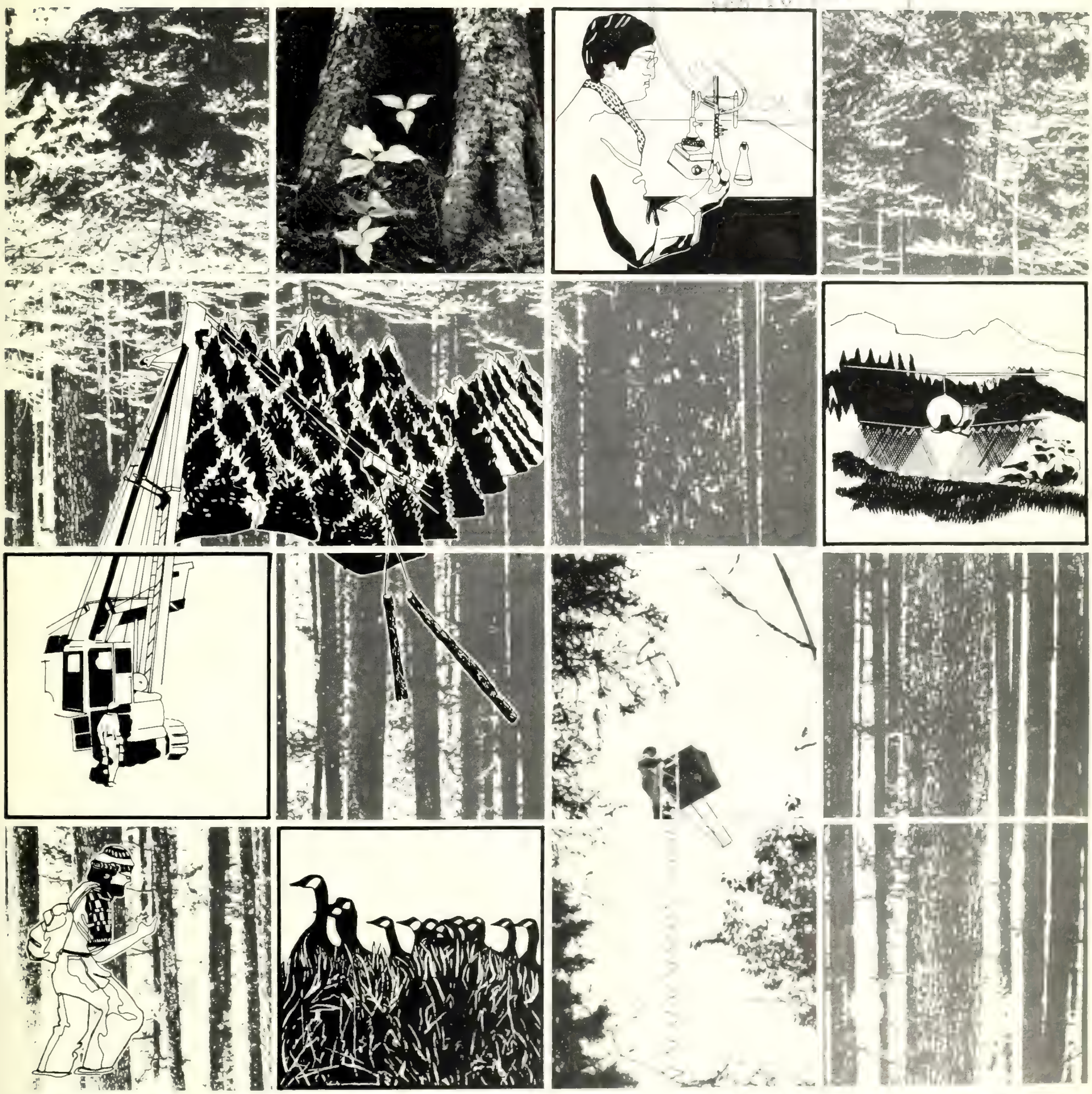
GPO 999-382

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture is an Equal Opportunity Employer. Applicants for all Department programs will be given equal consideration without regard to race, color, sex or national origin.

USDA Forest Service General Technical Report PNW-62

The Forester's Almanac
1977



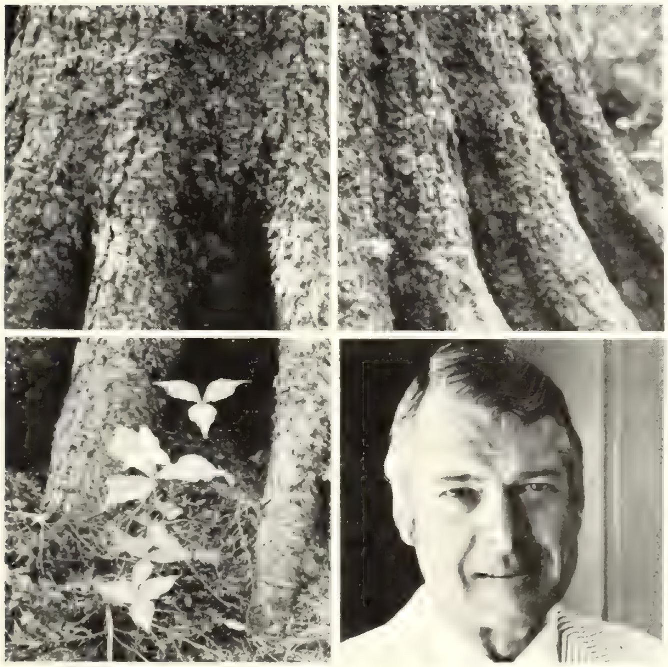
A catalog of publications from Forest Service research in the Pacific Northwest and Alaska—probably more than you've ever wanted to know. Leads about where to find more information on almost any topic: timber measurement, recreation, genetics, fire, insect and disease control, biology, ecology, Research Natural Areas, and much more (not necessarily in that order).

Pacific Northwest Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture
Portland, Oregon

The Forester's Almanac
1977

a catalog of forestry research publications
and other useful information from the

Pacific Northwest Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture
809 N.E. Sixth Avenue
P.O. Box 3141
Portland, Oregon 97208



Foresters (and others):

Forestry research has been conducted in the Pacific Northwest since the earliest days of forestry. Over the years, scientists and resource managers have learned many things about the forests and how to manage them for man's benefit. This Experiment Station has published literally thousands of reports on various aspects of forest management. But sometimes we get the feeling that too few people know anything about the Experiment Station—who we are, what we do, and how to get more information. In short, we're a little too close to our laboratories and a little too far from the woods.

We may never change that: it's just the nature of our work. But we can improve access to information. This publication is an attempt to do just that. I hope you will find the Almanac useful. Keep it on your desk or in some other relatively accessible place. If you use it and like it, let us know. Or call the editors and give them your ideas about how to improve future editions. We want to hear from you.

Robert F. Tarrant

Robert F. Tarrant
Director

ABOUT THE ALMANAC

This is not just another annotated bibliography. True, it contains summaries of many technical publications. But it's also meant for browsing. So you want to know something about a technical field other than your own? It's all here—most everything we've published on subjects as varied as dispersed recreation, skyline logging, forest fungi, and dozens of other topics.

Pick up the Almanac at coffee break, if nothing better comes along. Or read it during staff meetings. Even if you've been in forestry for many years, you should find something new and useful.

Publications, and other information in this catalog, are listed by subject matter in the contents (see page 3). An expanded table of contents is included at the beginning of each chapter. Bibliographies are found at the end of each section. There is also a list of authors so you can find out where to contact a particular scientist for more information.

Not every report the Station has published is included here. We have tried to include most of the reports published by this Experiment Station or written by staff members during the period 1970-76, plus many earlier reports that are especially useful. We have chosen primarily those that are of practical use to field people. But we also wanted to cover the scope of our research program, much of which is basic research. So you'll find references, but not always summaries, to articles that are very technical in nature.

Happy reading!

The Editors

TO ORDER PUBLICATIONS

Unless otherwise indicated, the reports listed here may be ordered from:

Publications Distribution
Pacific Northwest Forest and Range Experiment Station
P.O. Box 3141
Portland, Oregon 97208

Please use the complete reference when ordering. Check the bibliography at the end of each chapter for the correct literature citation. Do **not** use the reference number in parenthesis.

All publications listed here are not available from the Experiment Station. Some are out of print, or will be by the time you see this catalog. Our current policy is to keep publications in stock for 5 years. Only if demand is heavy, are they kept longer. If your request comes back indicating that the publication is out of print or not available, and you really can't do without it, try your local library or the PACFORNET resource library (for authorized users only).

Authors have large egos and tend to keep their reports longer than anyone else. A list of PNW Station authors in the back gives their locations so you can write for a copy.

More recent publications (those published since 1976) are not listed in this catalog. For a list of recent reports, consult the quarterly and annual publication lists (see page 4).

PRODUCED

In Information Services at the Pacific Northwest Forest and Range Experiment Station, P.O. Box 3141, Portland, Oregon 97208. Phone 503/234-3361, ext. 4992; FTS 429-4992.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such does not constitute an official endorsement or approval of any product or service by United States Department of Agriculture to the exclusion of others which may be suitable.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and/or federal agencies before they can be recommended.

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general information

Get on the Mailing List

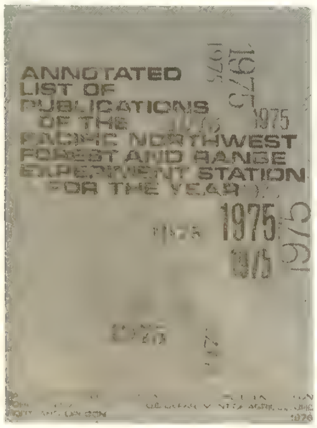
The Station publishes a list of available publications four or five times a year. It goes to the 7,000 or so names on our mailing list. If you get on the mailing list, this is the only report you will get from us automatically. All other publications must be requested individually.

Articles are categorized by subject and author. It pays to learn who is working in the subject area you are interested in, and then look for reports by those people.

To get on the publication list, write or call: Paul Barlow, Editorial Services, Pacific Northwest Forest and Range Experiment Station, P.O. Box 3141, Portland, Oregon 97208; 503/234-3361, ext. 4924, or FTS 429-4924.

There is also a yearly compilation called the *Annotated List of Publications of the Pacific Northwest Forest and Range Experiment Station.* Just because you get the quarterly list doesn't mean you'll get the annual list too. So if you want it, ask for it specifically.

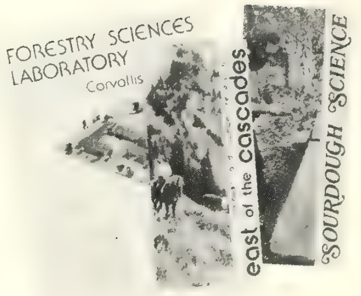
The quarterly list is great for keeping current with research information, but the annual list is better to file away. These are available currently, and for the past 1 or 2 years.


ANNOTATED LIST OF PUBLICATIONS OF THE PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION FOR THE YEAR
1975

The Invisible Forest Service

A full-color brochure describes the work of the Pacific Northwest Forest and Range Experiment Station in Oregon, Washington, and Alaska. Designed to acquaint the public with forestry research programs, it is also a useful introduction to forestry research for professionals in the field. Single copies may be obtained by writing to Publications Distribution at this Experiment Station.

Larger quantities of the publication may be obtained for handout at Forest Service offices in Oregon, Washington, or Alaska. For multiple copies, write or call Information Services at ext. 4992.

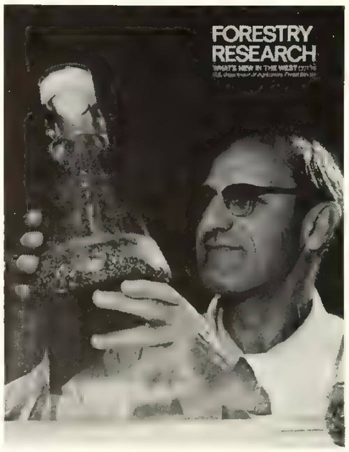


Project Brochures

Informational leaflets are available for most research projects. Order by subject matter or name of project (see organizational directory).

In addition, there are brochures on several of the facilities and programs:

•*Sourdough Science* is about forestry research in Alaska.
•*East of the Cascades* describes programs on the east side of the Cascades in Oregon and Washington.
•*The Forestry Sciences Laboratory* is about work underway at the Corvallis, Oregon, laboratory.



Forestry Research: What's New in the West

The four western Experiment Stations of the Forest Service also publish a magazine format news bulletin (approximately quarterly). It contains information about current research programs, and short articles about new research reports.

This is a report for forest resource managers, or anyone who is interested in forestry research, and it provides a general overview of some of the major new findings that may have application throughout the West.

Single copies of current issues are generally available at Experiment Station headquarters, but it's easier just to get on the mailing list (free of charge):

Forestry Research: What's New in the West
240 West Prospect Street
Fort Collins, Colorado 80521

RESEARCH PROGRESS 1974

Pacific Northwest Forest and Range Experiment Station
U.S. Department of Agriculture Forest Service

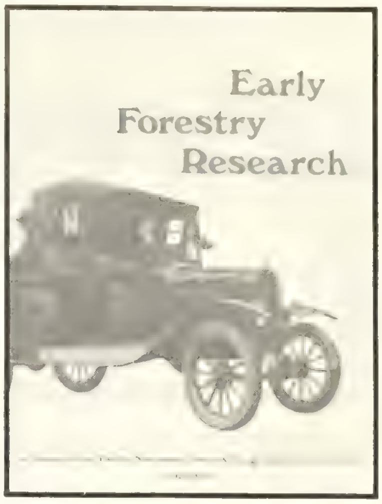
Annual Reports

The Experimental Station also publishes an annual, or nearly annual, progress report, outlining important new research findings. Many of these are still available, and should be requested by year. The latest report is dated 1974.

In lieu of an annual report for 1975, the Station published a historical report, outlining research activities from the beginning of the Station in 1925 to 1975.

The 32-page report contains a number of amusing anecdotes from the early years of the PNW Station. These include stories about Leo Isaac, the pioneering Douglas-fir scientist who flew a kite to learn more about seed dispersion; stories from Thornton Munger, the Station's first Director; and many more.

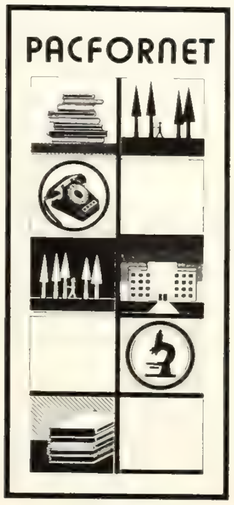
One story tells about Munger's insistence on careful budgeting: ''Munger put money into expensive items which were essential—a $500 'electrically driven calculating machine' and the little fleet of cars and trucks needed for Station work—but preached Yankee frugality in operating them. McArdle recalled that Munger had the front seat of the Station's first car 'remodeled with hinges so it could be folded back and make a bed. I was supposed to drive off into the bushes and use this instead of hotels,' he said.''


Early Forestry Research

Order the history booklet by the following citation:

Doig, Ivan. 1976. Early Forestry Research. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn., Misc. Publ., 32 p.

Leo Isaac [illegible]
[illegible]


PACFORNET

PACFORNET

Through a cooperative agreement, resource managers in several different organizations have access to forestry-related information through an information system called PACFORNET.

PACFORNET provides the latest scientific and technical literature to forestry professionals in five west coast states: Alaska, Washington, Oregon, California, and Hawaii. It is not a traditional reference library. Rather, it is a large information network with access to many technical information sources.

FOR A BROCHURE, WHICH INCLUDES A LIST OF WHO MAY USE PACFORNET, AND HOW, WRITE: Information Services, Pacific Northwest Forest and Range Experiment Station, P.O. Box 3141, Portland, Oregon 97208.

Services of PACFORNET include the monthly alert which lists new publications added to the system. Users in Alaska, Washington, and Oregon can get on the mailing list for the monthly alert through:

PACFORNET North
Forest Resources Library AQ-15
University of Washington 61-9719
Seattle, Washington 98195

Users in California are served by:

PACFORNET South
PSW Science Literature Service
P.O. Box 245
Berkeley, California 94701

research facilities

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headquarters

PNW: Research Headquarters

The Pacific Northwest Forest and Range Experiment Station, headquartered in Portland, Oregon, is the administrative hub of a research program that has eight laboratories in three western states. Research activities span the length of the continent, from the tundra of interior Alaska, through the dense coastal forests of Alaska, Oregon and Washington, and into the semi-arid zone east of the Cascades.

Administrative offices for this research network are located in the Forum Building in northeast Portland. The mailing address is **P.O. Box 3141, Portland, Oregon** 97208, phone: 503/234-3361 or FTS 429 + extension. This address and phone number will reach the following:

Director: Robert F. Tarrant
(ext. 4907)

Deputy Director: Robert A. Hann
(ext. 4908)

Assistant Director for Planning and Applications:
Eldon Estep (ext. 4908)

Assistant Director, Central Research Units:
Donald F. Flora (ext. 4928)

Assistant Director, North Research Units:
vacant

Assistant Director, South Research Units:
Robert M. Romancier (located in Corvallis; phone 503/757-4381 or FTS 420-4381—see page 8)

Assistant Director for Research Support Services:
Charles J. Petersen (ext. 4909)

Biometrician: John W. Hazard (ext. 4948)

Administrative Officer: Barbara Hague
(ext. 4950)

Architect: A.P. DiBenedetto (ext. 4905)

Editor: George M. Hansen (ext. 4927)

Public Information Officer: Louise Parker
(ext. 4992)

In addition to the Director and his staff, the Portland office also houses several research programs not found at other Station field locations:

Program Manager for Forest Residues:
Edward H. Clarke (ext. 4811)

Economics of Forest Land Management:
Roger D. Fight (ext. 4931)

Foreign Trade Analysis:
David Darr (ext. 4931)

Timber Measurement and Management Planning in the Northwest:
Dean S. DeBell, Acting Project Leader
(see Olympia Laboratory, page 8)

Multi-Resource Supply Analysis for the Pacific Coast States:
Charles Van Sickle (ext. 4935)

Timber Quality and Product Yield Potential of Western Softwood Resource:
Richard O. Woodfin, Jr. (ext. 4966)

laboratories

East of the Cascades

It's a different world on the other side of the mountains. For this reason, PNW has established three laboratories in Oregon and Washington to investigate forest, range, and brushland ecosystems east of the Cascades.

The laboratories are located at Wentachee, Washington, and La Grande and Bend, Oregon. In Wenatchee, the emphasis is on watershed research. In La Grande, scientists are specializing on wildlife and range problems. Fire and timber are the focus of the research at Bend.

Addresses and phone numbers for each of the three east-side labs are as follows:

Forest Hydrology Laboratory
1133 N. Western Avenue
Wenatchee WA 98801
Phone: 509/662-4315
FTS: 390-0315

Range and Wildlife Habitat Laboratory
"C" and Gekeler Lane
Rt. 2, Box 2315
La Grande OR 97850
Phone: 503/963-7122
FTS: 221-0111

Silviculture Laboratory
1027 NW Trenton Avenue
Bend OR 97701
Phone: 503/382-6922
FTS: 422-6283

Wenatchee

La Grande

Bend

An information brochure on the research programs at the three laboratories is available from Information Services, PNW Station, P.O. Box 3141, Portland OR 97208. Ask for *Forest and Range Research —East of the Cascades.*

Following are the major research units and project leaders at each laboratory:

Water Yield—Improvement and Erosion Control—Interior River Basin Forests—Arthur R. Tiedemann, Wenatchee, Washington.

Wildlife Habitat and Range Ecosystem Research—Jack W. Thomas, La Grande, Oregon.

Silviculture of Interior Forest Types—Robert E. Martin, Bend, Oregon.

Seattle

An office at 4507 University Way in Seattle, Washington, houses two PNW research programs. The building can hardly be called a laboratory. The location, in the University District in Seattle, was chosen because of it's proximity to the University of Washington.

The full address is Pacific Northwest Forest and Range Experiment Station, 4507 University Way NE, Seattle, Washington 98105. Phone: 206/442 + extension. Extension 7817 will get Wildland Recreation, 7815—Forest Residues, and 7814—Forest Engineering. FTS users should dial 399 + the extension.

Following are the major research units and project leaders:

Wildland Recreation Research, Roger Clark.

Logging Systems for Fragile Mountain Terrain, Hilton H. Lysons.

Sourdough Science

Scientists from the Forestry Sciences Laboratory in Juneau and the Institute of Northern Forestry in Fairbanks are working to learn more about the complex world of the Alaskan forests.

Both laboratories are making significant contributions to man's knowledge of these extensive forests. The information is being used by federal, state, and local agencies and native corporations to plan environmentally sound forest resource management programs.

The mission of the Forestry Sciences Laboratory in Juneau is to determine the relationships which exist between various components of the coastal forest ecosystem. To accomplish this task, scientists are working in the areas of timber harvest, fisheries biology, timber stand regeneration, forest insect and disease problems, and other related areas.

The forests of interior Alaska differ from those along the coast. For this reason, scientists at the Institute of Northern Forestry in Fairbanks are faced with different research problems. Wildfire is one of the major keys to an understanding of the life history of the forests of the interior. Other research areas include wildlife habitat, silvicultural systems, and forest insect and disease research.

The Forestry Sciences Laboratory is located in the Federal Building in downtown Juneau. Address: P.O. Box 909, Juneau AK 99802. Phone: 907/586-7301.

The Institute of Northern Forestry is located in Fairbanks, Alaska, adjacent to the University of Alaska. Address: Institute of Northern Forestry, Fairbanks AK 99701. Phone: 907/479-7313.

FTS users can dial a special number in Seattle, Washington, (8-399-0150) and furnish the operator with the number of either lab.

An information brochure, *Sourdough Science,* is available from Information Services, PNW Experiment Station, P.O. Box 3141, Portland OR 97208.

The following are the major project areas and project leaders at both laboratories:

Ecology of Southeastern Alaska Forests—Donald C. Schmiege, Juneau.

Ecology and Management of the Taiga (Subarctic Forests)—C. Theodore Dyrness, Fairbanks.

Forest Survey for Alaska—O. Keith Hutchison, Juneau.

Olympia's Forestry Sciences Laboratory

There are over 25 million acres of commercial forest land in Oregon and Washington including an estimated twelve million acres of Douglas-fir, western hemlock and associated species. Each year the demands on these forested lands increase. At PNW's Forestry Sciences Laboratory in Olympia, scientists are studying the intensive culture of Douglas-fir. Researchers are looking at the relationship of growing space to maximum tree growth and the effects of fertilization on increasing the productivity of the Douglas-fir forests.

The Forestry Sciences Laboratory can be reached by writing to 3625 - 93rd Ave. SW, Olympia WA 98502. Phone: 206/753-9470, FTS: 434-9470. The only research unit presently at Olympia is the Intensive Culture of Douglas-fir and Associated Species directed by Dean S. DeBell.

Corvallis Phase I Lab

Forestry Sciences Laboratory
Corvallis, Oregon

The Corvallis Laboratory is the largest of six field locations of the Experiment Station and the second largest Forest Service research facility in the country.

The laboratory is located next to the School of Forestry on the Oregon State University campus. Address: 3200 Jefferson Way, Corvallis OR 97331. Phone: 503/752-4211 or FTS: 420 + extension. Extension 4381 will get Assistant Director Robert M. Romancier.

Major aspects of the research program at Corvallis include: forest genetics, ecology, silviculture, insect and disease problems, reforestation systems, chemicals in the forest environment, watershed protection, anadromous fish habitat, and economics research.

The laboratory was formally dedicated in 1962. A close relationship is maintained between the scientists at the laboratory and the university, stimulating cooperative research throughout the scientific community.

An information brochure is available from the Information Office, PNW Experiment Station, P.O. Box 3141, Portland, Oregon 97208.

The following are the major research units and project leaders:

Reforestation Systems in the Pacific Northwest—Ronald E. Stewart (ext. 4464).

Ecological Basis for Management of Northwest Coniferous Forests—Jerry F. Franklin (ext. 4587).

Breeding Northwest Trees—Roy R. Silen (ext. 4235).

Managed Forest Watersheds in the Douglas-fir Region—Logan A. Norris (ext. 4586).

Population Ecology and Impacts of Forest Insects of the Pacific Northwest—Boyd E. Wickman (ext. 4263).

Diseases of Western Forest Insects—Clarence G. Thompson (ext. 4240).

Physiology and Behavior of Forest Insects of the Pacific Northwest—Gary E. Daterman (ext. 4224).

Strategies for Forest Disease Control—Earl E. Nelson (ext. 4285).

Mycorrhizal Applications in Ecosystem Management—James M. Trappe (ext. 4220).

Economics of Regional and Local Impacts of Forest Resource Management Decisions—Con Schallau

experimental forests and ranges

introduction

In 1930, the Forest Service began to establish experimental areas where Forest Servic scientists could carry out long- and short term field studies. These experimental area have been selected to represent importan forest or range types. All are under th administrative control and protection of th government agency or private owner, bu agreements provide that the Experiment Stations control management activities to mak sure they are compatible with researcl objectives.

In addition to accommodating studies c many kinds, experimental areas also provid settings in which to demonstrate forestr practices on a commercial scale to manager of both public and private forest lands

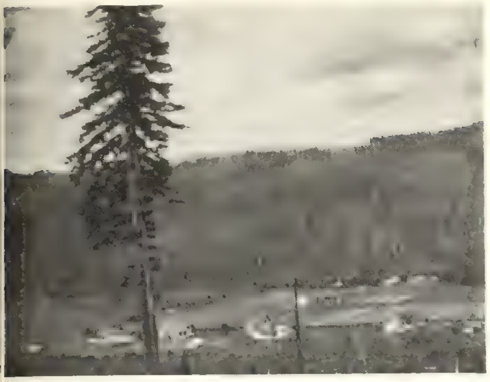
Often, as research provides knowledge abou the ecology and silviculture of forests, th kinds of studies carried out on a particula experimental area change. New forest management problems demand solutions, o new directions for research are indicated b past findings. Many studies continue fo decades and data thus accumulated mak the areas even more valuable for subsequen studies.

western oregon & washington

wind river experimental forest

Established in 1933
Size: 10,185 acres
Elevation: 1,100-4,000 feet
Vegetation: Douglas-fir, western hemlock
Location: Gifford Pinchot National Fores
Washington

The most historic of the western Experimental Forests is in the Wind River Valley north of Carson, Washington. It was her that forestry research in the Pacific Northwest began in 1910, with studies at th Wind River Nursery to improve nurser and forest planting practices. The nurser had been established a few years earlier t supply trees to reforest the valley which ha lost most of its old-growth timber in severe fire in 1902.



Wind River Station and Nursery, 1914.

In 1913 the Wind River Forest Experiment Station was established, and studies were conducted in tree growth and heredity, forest management, and fire protection. In 1924, when the Pacific Northwest Forest and Range Experiment Station was established (with headquarters in Portland, Oregon), the Wind River Station became a field laboratory of the new regional research agency. In 1933, the area was officially designated as the Wind River Experimental Forest.

Many techniques for managing Douglas-fir and hemlock forests have developed from studies done on the Experimental Forest. Growth and heredity studies established as early as 1912 are still furnishing information on genetics and tree growth. The Experimental Forest includes an 1,180-acre Research Natural Area, established in 1934, and the Wind River Arboretum, established in 1912.

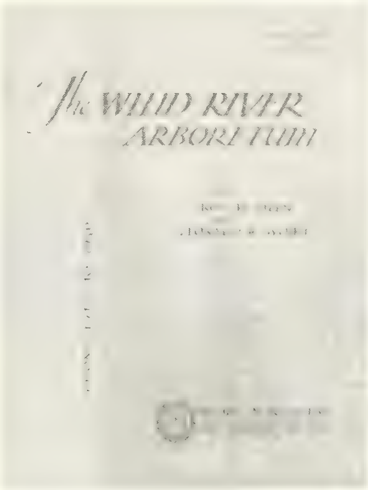
wind river experimental forest

A brochure on the Experimental Forest (1) and information on several of the important studies can be obtained at the Wind River Ranger Station or by writing to Information Services at the PNW Experiment Station.

A PIONEER SEARCH FOR BETTER KINDS OF TREES FOR THE NORTHWEST ....

WIND RIVER ARBORETUM

A Pioneer Search for Better Trees (2), a brochure about the arboretum, describes how trees from all temperate parts of the world were planted to compare their growth with native northwest species and what happened to them. Progress of the arboretum trees from 1912 to 1956 is summarized in a publication by Roy Silen and Leonard Woike (3). The major conclusion—as most foresters now know—is that native trees are better adapted to the site and grow best in the long run.



The WIND RIVER ARBORETUM

h.j. andrews experimental forest

Established in 1948
Size: 15,000 acres
Elevation: 1,500-5,000 feet
Vegetation: Douglas-fir
Location: Willamette National Forest, Oregon

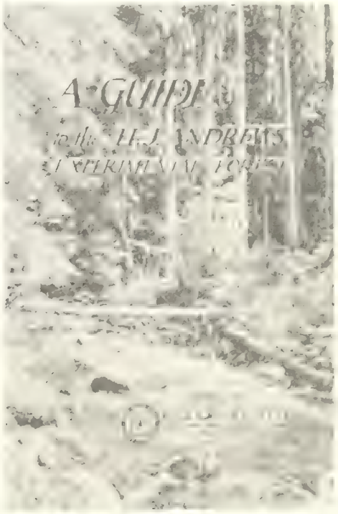
This Experimental Forest lies along the west slope of the Cascade Range, about 50 miles east of Springfield, Oregon, and occupies the entire 22½-square-mile drainage of Lookout Creek, a tributary of the McKenzie River.

At the time the forest was established for forest management studies, access was by foot or horseback. To facilitate a timber harvest program in the early 1950's, an extensive road plan was developed to reach planned harvest areas. Since that time, many studies of salvage logging methods, time-cost effectiveness, forest regeneration, genetic adaptability of seed to site, and forest protection from wind, fire, disease, and insects have been carried out.

The first watershed study in the Pacific Northwest was begun here in 1952, when trapezoidal flumes were installed on each of three small drainages. Additional watershed studies were instrumented in 1963 and 1968. One of these (watershed 10) is the most intensively studied in the world. Data gathered here is used to relate forest management activities to soil and nutrient losses and to set standards for forest water quality.

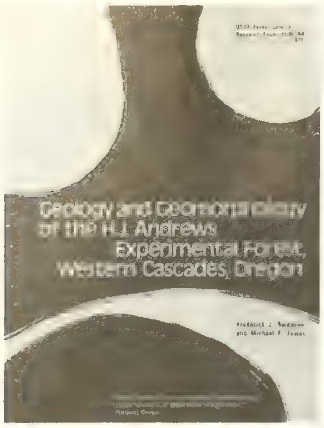
University researchers working under the Coniferous Forest Biome of the International Biological Program have extensive studies covering the full range of ecological processes and forest conditions of the Experimental Forest. Much of this effort has been directed toward basic soil and nutrient studies of the Douglas-fir forests in watershed 10.

A descriptive guide to the Experimental Forest, published in 1959, is available (4).



A GUIDE to the H.J. ANDREWS EXPERIMENTAL FOREST

Of the several hundred scientific papers published from research conducted at the H.J. Andrews Experimental Forest, three are recommended for basic information about the vegetation, soils, and geology. A preliminary classification of forest communities is provided in a 1974 publication, *A Preliminary Classification of Forest Communities in the Central Portion of the Western Cascades in Oregon,* by C.T. Dyrness, J.F. Franklin, and W.H. Moir (5).



Geology and Geomorphology of the H.J. Andrews Experimental Forest, Western Cascades, Oregon

Geology and Geomorphology of the H.J. Andrews Experimental Forest, Western Cascades, Oregon, by Frederick Swanson and Michael James (6)

The development and productivity of forest ecosystems is closely linked with the action of geologic and geomorphic processes on the landscape, particularly in areas such as the western Cascades, where erosion rates are high and deep-seated and shallow mass soil movements are frequent. An understanding of these processes is important to forest managers because land management activities may increase erosion and soil movement. This 13-page paper summarizes the recent geomorphic history of the Experimental Forest.

Also see *A Checklist of Vascular Plants on the H.J. Andrews Experimental Forest, Western Oregon,* by Jerry Franklin and Ted Dyrness (7). This publication is based on the results of intensive plant collecting which began on the forest in 1958. It lists 480 categories of plants and indicates in which of the two primary vegetative zones (western hemlock and Pacific silver fir) they are found.

cascade head experimental forest

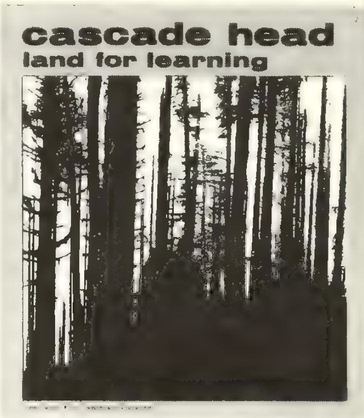
Established in 1934
Size: 11,890 acres
Elevation: 0-1,750 feet
Vegetation: Western hemlock, Sitka spruce
Location: Siuslaw National Forest, Oregon

A high ridge jutting into the Pacific Ocean on the central Oregon coast is the spectacular setting for the Cascade Head Experimental Forest, established for studies of forest management in typical fogbelt coastal forests. Situated between the Salmon River estuary and the town of Neskowin, it is representative of coastal forests that extend 1,800 miles from California into Alaska.

Research began with establishment of permanent plots to measure the yield of Sitka spruce-western hemlock, Douglas-fir, and alder stands. Later experimental cuttings of commerical size were made, and planting, brush control, and wind damage have been studied. Studies were gradually expanded to include all aspects of the ecology of fast-growing spruce-hemlock forests, from seed fall to nutrient cycling.

In 1941, the Neskowin Crest Research Natural Area was established on 700 acres of the Experimental Forest to preserve spruce and hemlock stands along the Pacific Ocean for research and education.

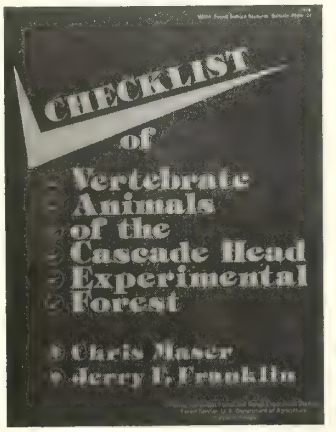
In December 1974, a new dimension was added to research in the Experimental Forest when the western portion of the forest was included in the 8,900-acre Cascade Head Scenic-Research Area established by Congress. The Scenic-Research Area preserves Cascade Head and Salmon River estuary immediately to the south for basic ecological research, scenic enjoyment, and educational purposes. This designation is expected to stimulate and expand research and demonstration in the Experimental Forest.



cascade head
land for learning

Cascade Head: Land for Learning, a descriptive brochure about the Scenic-Research Area published in 1976, contains information about the Experimental Forest (8).

A list of 64 reports of studies carried out on the Experimental Forest is available from Information Services at Station headquarters in Portland.



CHECKLIST
of
Vertebrate
Animals
of the
Cascade Head
Experimental
Forest

Chris Maser
Jerry F. Franklin

Checklist of Vertebrate Animals of the Cascade Head Experimental Forest, by Chris Maser and Jerry Franklin is an annotated checklist of 9 amphibians, 2 reptiles, 35 birds, and 40 mammals found on the Experimental Forest (9).

south umpqua experimental forest

Established in 1951
Size: 600 acres
Elevation: 2,375-3,520 feet
Vegetation: Mixed conifer
Location: Umpqua National Forest, Oregon

The Umpqua Experimental Forest is about 50 miles southeast of Roseburg, Oregon, and consists of the watersheds of four tributaries to the South Umpqua River. The area is representative of the southwest Oregon mixed conifer timber type, consisting of Douglas-fir mixed with sugar and ponderosa pine. This forest type extends from the North-South Umpqua River divide south into California.

South Umpqua Falls

Drainage basin studies began in 1961 with measurements of natural conditions on the four watersheds. In 1969, studies of nutrient and soil balance were begun to assess the possible long-term impacts of timber harvesting on forest productivity.

Roads were constructed on three of the watersheds in 1971, and in 1972 the timber was harvested in large clearcuts on one watershed, small clearcuts on another, and shelterwood cuts on the third. The fourth was left uncut as a control.

In 1976, the Environmental Protection Agency joined in a cooperative study of the effect of timber harvesting on the potential for algae production in water downstream from timber harvest areas.

voight creek experimental forest

Established in 1947
Size: 230 acres
Elevation: 830-1,140 feet
Vegetation: Douglas-fir
Location: Southwest Washington

Located on forest land belonging to the St. Regis Paper Company southwest of Tacoma, Washington, the Voight Creek Experimental Forest was established for studies and demonstrations of forest management in second-growth Douglas-fir. At the time the Forest was established, trees were 37 years old. They had originated after clearcutting and repeated burns.

General view of area thinned in 1949 Plot 9, Compt A 1

Studies have been made of the effects of thinning on tree and stand growth and yield, on stem form and crown development of individual trees, and on seed production and litterfall.

Other studies have concerned the labor requirements and costs of thinning, the financial aspects of pruning, and the relationships between thinning and tree damage from various sources.

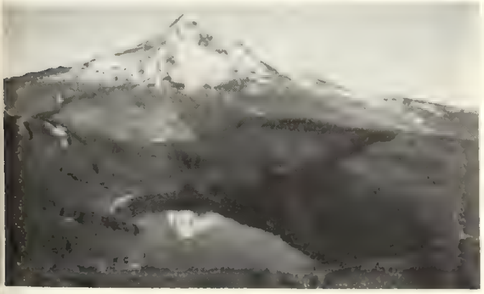
More recently, fertilizer has been applied to some of the plots to determine its effect on tree and stand growth in previously thinned and unthinned stands approaching harvest age.

bull run experimental watershed

Established in 1957
Size: 945 acres
Elevation: 2,750-3,560 feet
Vegetation: Douglas-fir, western hemlock
Location: Mt. Hood National Forest, Oregon

The experimental watershed consists of the drainages of three unnamed branches of Fox Creek, a tributary of the South Fork of the Bull Run River. The area is located within the 142,000-acre Bull Run Reserve, which was set aside by Presidential proclamation in 1892 to protect the water supply of the City of Portland. The reserve is managed by the Mt. Hood National Forest.

Timber cutting was begun in 1957 in a program designed to prevent natural wildfires within the reserve. Watershed studies were begun the same year to evaluate the effects of timber harvesting on water supply, water quality, and soil and nutrient balance. Three drainage basins were instrumented for this purpose in 1957.



mccleary experimental forest

Established in 1948
Size: 340 acres
Elevation: 300-600 feet
Vegetation: Douglas-fir
Location: Southwest Washington

This forest was established on forest land of the Simpson Timber Company west of Olympia, Washington, to investigate thinning as a means of increasing the recoverable volume of young-growth stands, primarily Douglas-fir. Trees on the eastern portion of the Forest originated after a severe burn and were 55 years old when the Experimental Forest was established. Younger trees (age 39) originated following logging on the western portion of the forest.

The effects of light and frequent thinning on growth and yield have been studied. In addition, logging costs and production rates have been investigated.

Other studies have covered mortality salvage, crown and stem development of individual trees, and natural regeneration. Currently, the use of various fertilizers to improve tree growth is being investigated on some of the plots.

A Guide to the McCleary Experimental Forest, a descriptive folder prepared in 1954 is available (10).

eastern oregon & washington

starkey experimental forest & range

Established 1940
Size: 27,000 acres
Elevation: 3,680-5,000 feet
Vegetation: Ponderosa pine, Douglas-fir, western larch
Location: Wallowa-Whitman National Forest, Oregon

Located southwest of La Grande, Oregon, in the Blue Mountains, the Starkey Experimental Forest and Range has been grazed by livestock since the middle 1860's and administered as a grazing allotment by the Forest Service since 1907. Grazing management research by Station scientists began in 1940. In 1954, studies in watershed management, forest ecology, and livestock-big game relationships were begun. More recently, studies of soil fertility, non-game wildlife, silvicultural methods, prescribed burning, recreation, and effects of grazing on riparian habitats have been added.

pringle falls experimental forest

Established 1931-1954
Size: 11,055 acres
Elevation: 4,000-6,230 feet
Vegetation: Ponderosa, lodgepole, and sugar pine, and white fir
Location: Deschutes National Forest, Oregon

Located about 35 miles south of Bend, Oregon, the Pringle Falls Experimental Forest is composed of two units: The Pringle Butte unit of 7,540 acres, established in 1931; and the Lookout Mountain unit of 3,515 acres, established in 1937.

The Forest is primarily ponderosa and lodgepole pine, mixed with white fir, noble fir, and some Douglas-fir and sugar pine at higher elevations on north slopes.

The Pringle Falls Research Natural Area, established in 1936, and located in the Pringle Butte unit, consists of 560 acres of typical old-growth ponderosa pine and 600 acres of lodgepole pine.

Studies of the silviculture and management of eastside timber species have been carried out on the Forest since its establishment. These include growth and mortality, levels of growing stock, thinning, brush control, methods of cutting, and prescribed burning.

entiat experimental forest

Established in 1971
Size: 5,040 acres
Elevation: 1,800-7,000 feet
Vegetation: (pre-fire) Ponderosa pine, Douglas-fir, lodgepole pine, western redcedar, and whitebark pine
Location: Wenatchee National Forest, Washington

In 1957, the area that is now the Entiat Experimental Forest was selected for studies of water yield from forest land, water quality, vegetation succession, and site productivity in response to specific forest practices. Gaging stations were constructed on the watersheds of three adjoining tributaries of the Entiat River about 45 miles from Wenatchee, Washington.

On August 24, 1970, a lightning-caused forest fire burned 45,000 acres of the experimental watersheds, and the hydrologic studies had to be reoriented from their original objectives. Most of the timber was gone. However, researchers redesigned their studies to evaluate both the effects of fire on the environment and ways of rehabilitating areas damaged by fire. The shift in research emphasis was possible because almost 10 years of hydrologic measurements were available and gages and other installations were still usable.

Studies of the effect of fire and revegetation of burned areas continue to provide guidelines for land managers faced with erosion and other problems that follow large fires. See a descriptive brochure about the Experimental Forest titled, *Operation Phoenix,* by Thomas M. Baugh (11).

southeast alaska

maybeso experimental forest

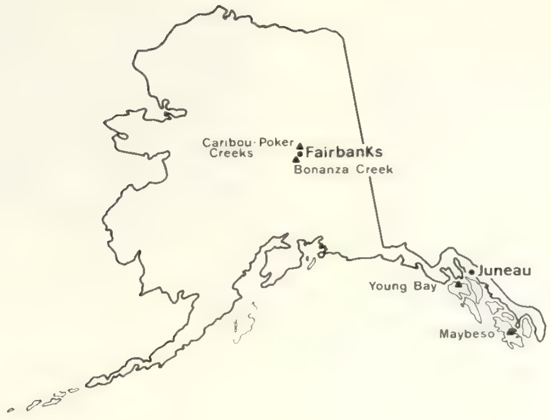
Established in 1956
Size: 11,102 acres
Elevation: 0-3,392 feet
Vegetation: Western hemlock, Sitka spruce, western redcedar, and Alaska cedar
Location: Tongass National Forest, Alaska

The Maybeso Creek watershed on Prince of Wales Island was selected in 1949 for studies of the effects of logging on the spawning of pink and chum salmon because it contained a variety of timber stand conditions, a suitable stream, and was soon to be logged. Much of the early Forest Service research on salmon spawning habitat was done here. These studies were concluded in 1966, when fish habitat research shifted from major stream channels to small tributary streams.

After the timber on 2,500 acres of the Experimental Forest was removed by clearcutting, studies of natural regeneration were carried out between 1955 and 1962. Research on soil movements and their relation to logging practices was begun following a large scale soil mass movement in the Maybeso Valley in 1961. These studies have produced information which is now guiding cutting practices on the Tongass National Forest.

Active research on the Experimental Forest is now limited to studies of management of young, even-aged stands of western hemlock and Sitka spruce. This research is expected to increase as the stands mature and silvicultural and logging methods can be tested and demonstrated.

In 1969 the Experimental Forest was reduced by about 320 acres to provide for a state ferry terminal and a highway on a portion of the forest. The area is now accessible by ferry and is on a growing road system on Prince of Wales Island, making it an accessible study site.



young bay experimental forest

Established in 1959
Size: 6,425 acres
Elevation: 0-3,604 feet
Vegetation: Western hemlock, Sitka spruce
Location: Admiralty Island, Alaska

Two streams on steep terrain on the northeastern shore of Admiralty Island were selected in 1958 for studies of the spawning habitat for pink and chum salmon. Gaging stations were installed to record water levels and temperatures.

Studies of spawning habitat have been carried out since 1966, using an artificial stream channel in which discharge, velocity, gradient, gravel composition, and amount and type of sedimentation can be controlled.

While allowing control of these stream variables, the artificial channel maintains the characteristics of a natural stream, and techniques developed there can be applied to fish habitat studies in natural streams.

interior alaska

bonanza creek experimental forest

Established in 1964
Size: 12,500 acres
Elevation: 400-1,300 feet
Vegetation: White and black spruce, paper birch, aspen, balsam poplar, and tamarack
Location: West of Fairbanks, Alaska

Located on land managed by the Alaska State Division of Lands, Department of Natural Resources, the forest contains a variety of upland, lowland, muskeg, and flood plain forests, a portion of the Tanana River and two islands, one with a 300-year-old stand of white spruce.

Early research on the Experimental Forest consisted of monitoring the ecological processes of undisturbed forest ecosystems. Studies to evaluate the effects of timber harvesting and fire on forest types were begun in 1971, and in 1975 studies of hardwood regeneration were added. A 1976 grant from the National Science Foundation will fund additional monitoring.

caribou-poker creeks research watershed

Established in 1969
Size: 40.8 square miles
Elevation: 700-2,525 feet
Vegetation: Black spruce, aspen, birch, alder, white spruce
Location: 20 miles north of Fairbanks, Alaska

Poker Creek, with its tributary, Caribou Creek, rises in the high ridges of Poker Dome and drains into the Chatanika River at Poker Flats. The watersheds drain an area of 40.5 square miles, are well covered with timber, and include both north-facing (permafrost) and south-facing (non-permafrost) basins.

Development of the research area was a cooperative effort by 12 agencies and university departments, coordinated through the Inter-Agency Technical Committee for Alaska. It is the only permafrost-dominated subarctic area in the United States which is dedicated to hydrology and environmental research. This basin has been designated an Experimental Ecological Reserve by The Institute of Ecology.

Most efforts to date have been oriented toward collecting baseline data, making inventories, and improving ground access to the area.

research natural areas

In 1927, the Forest Service set aside a 4,500-acre ponderosa pine forest in Arizona for scientific study. The action was taken partly in response to proposals by early Forest Service officials to preserve examples of the typical timber types as reference points and guides for future forest studies. The officials feared that all primeval forest stands might someday disappear.

Action to preserve areas in the Pacific Northwest got underway in 1927 also, with formation of the Pacific Northwest Research Natural Area Committee. Thornton Munger, Station Director, was the first chairman of the committee.

Since that beginning in 1927, other federal land management agencies have joined the Forest Service in a cooperative program to establish a nationwide system of reserves to represent not only all timber types but all major ecosystems. Other public agencies and private organizations have joined the movement to preserve natural areas.

The purpose of these areas is to provide natural scientists with a place to study plants, animals, environments, and ecological processes which have not been altered by man's activities. The areas also serve as benchmarks for assessing the extent of man's impact on diverse environments and as preserves of gene pools for plant and animal species.

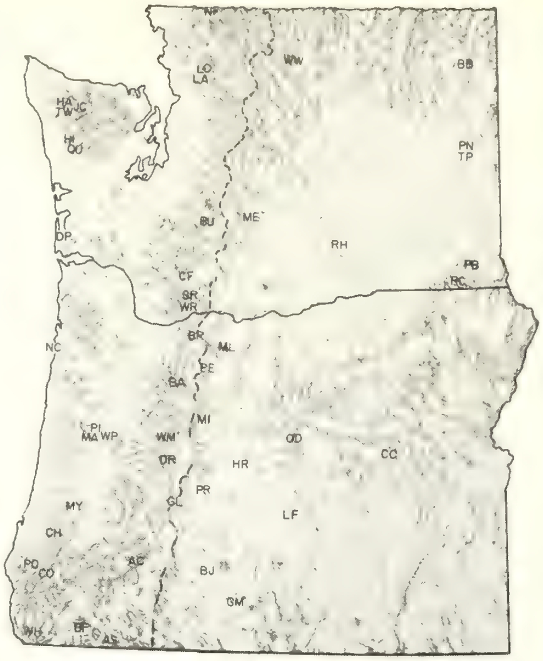
Wheeler Creek, A Milestone

On May 3, 1973, in the southwest corner of Oregon, the Forest Service held a special ceremony to mark the designation of the 100th Research Natural Area on National Forest land. Visitors gathered in a cathedral-like grove of redwoods to dedicate the Wheeler Creek Research Natural Area. The area was added to the natural area system to represent coast redwood (*Sequoia sempervirens*) growing at the northern limit of its range.

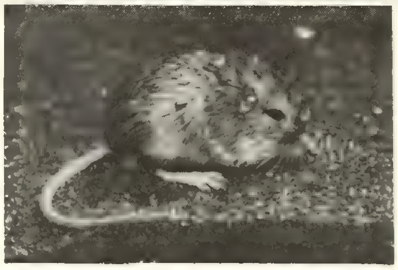
Federal Research Natural Areas in Oregon and Washington: A Guidebook for Scientists and Educators, by Franklin, Hall, Dyrness, and Maser (12)

This guide provides detailed descriptions of physical and biological features of 48 Research Natural Areas in Oregon and Washington. It includes maps, photographs, and indices to areas by vegetation type and plant and animal species. It also includes instructions to scientists on use of the areas. Descriptions of newly added areas are published as supplements to the guide.

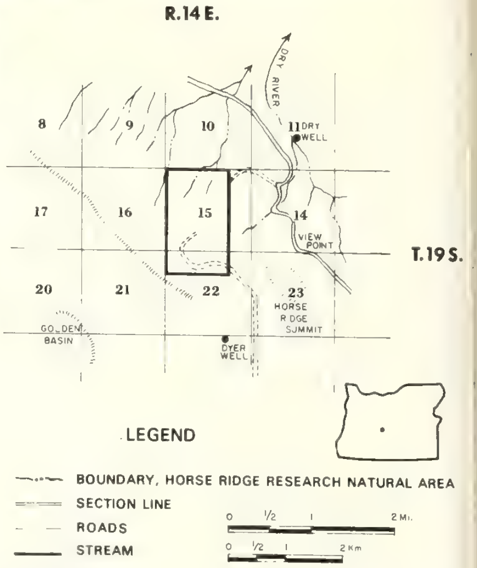
Typical closed stand of Oregon white oak near summit of Pigeon Butte.



Geographic distribution of established Federal Research Natural Areas in Oregon and Washington.



The most abundant mammal on the natural area (Rattlesnake Hills), the Great Basin pocket mouse, (Perognathus parvus).



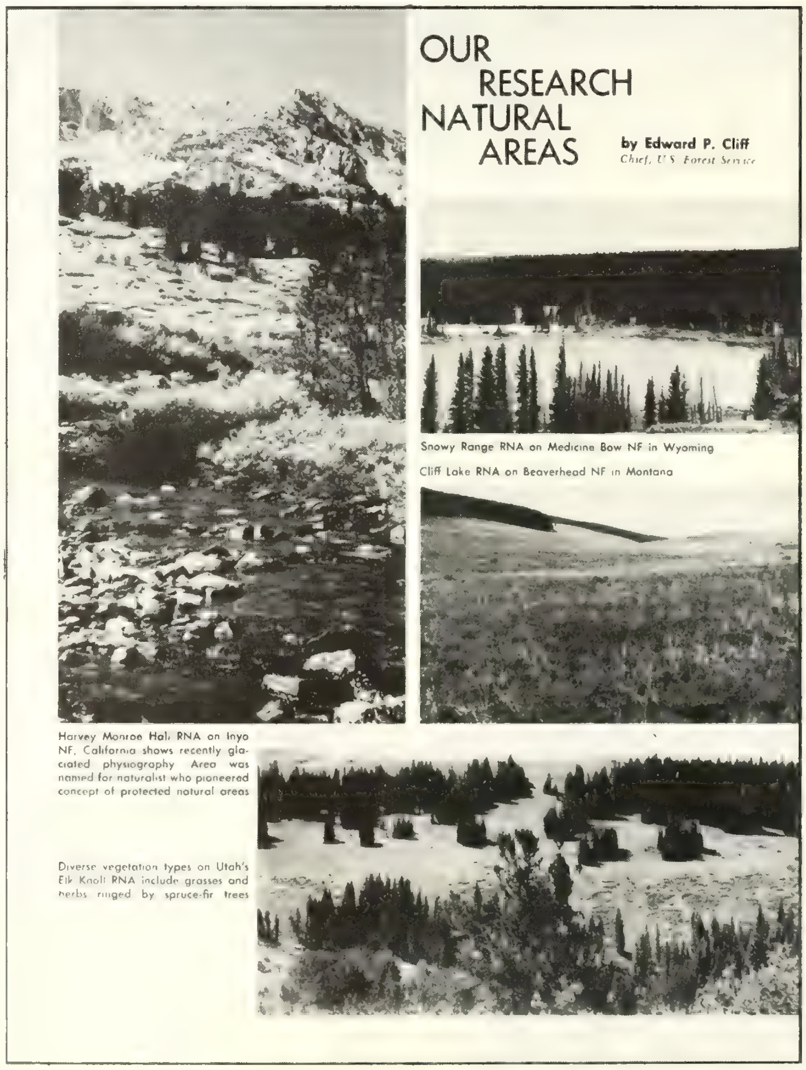
Horse Ridge Research Natural Area, Deschutes County, Oregon.

Research Natural Area Needs in the Pacific Northwest, by C.T. Dyrness, et al. (13)

A master plan for a comprehensive system of Research Natural Areas for Oregon and Washington is outlined in this 1975 publication. It is the first such plan for any part of the United States. By defining the scope and content of a minimal scientific preserve system, the book provides assistance to federal, state, and local agencies in preparing comprehensive land-use plans. It describes 316 types of areas needed (in addition to the 60 areas established at the time of publication) to complete an adequate system of reserves for the two states. It has become the standard reference for all public and private natural area efforts in the Pacific Northwest.

More on Natural Areas

Reprints of short articles about Research Natural Areas provide additional information. These include one by Franklin, Jenkins, and Romancier on the contribution of Research Natural Areas to environmental quality programs(14); another by Romancier on the need for coordinated action to inventory and set aside additional areas(15); one by Moir which summarizes the history and extent of the movement, and includes 35 references and notes dating from 1899 (16); and one by Cliff on the Forest Service program of Research Natural Areas(17).



OUR
RESEARCH
NATURAL
AREAS

by Edward P. Cliff
Chief, U.S. Forest Service

Snowy Range RNA on Medicine Bow NF in Wyoming

Cliff Lake RNA on Beaverhead NF in Montana

Harvey Monroe Hall RNA on Inyo NF, California shows recently glaciated physiography Area was named for naturalist who pioneered concept of protected natural areas

Diverse vegetation types on Utah's Elk Knoll RNA include grasses and herbs ringed by spruce-fir trees

research facilities-bibliography

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ecosystems, classification

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plant keys

Important Plants on National Forest Ranges of Eastern Oregon and Eastern Washington, by Elbert H. Reid (1)

Simple keys and descriptions are given on the occurrence and forage value of important plants on the national forest ranges of eastern Oregon and eastern Washington. Published in May 1942, it is still a useful guide which has not been updated. Species are listed only if they are important range plants or are abundant on the range.

Identification of Rotten Logs in the Coastal Forests of Oregon and Washington, by Don Minore (3)

Why on earth would anyone want to identify a rotten log? Certainly not to sell it at the mill. But perhaps as an aid in studying the success (or lack of success) of young seedlings growing on rotten logs.

This is a publication for a special kind of forest scientist—one who studies forest regeneration, especially in coastal areas of the Pacific Northwest. In the Olympic rain forest, more than 70 percent of the spruce and hemlock reproduction is on rotten logs. There it may be important for researchers to know what species of log is best suited for growing young trees.

This guide should make field identification easier. It provides a key and species descriptions for decaying logs of the most common Oregon and Washington coastal species: Sitka spruce, western hemlock, Douglas-fir, the true firs, western redcedar, red alder, and bigleaf maple.

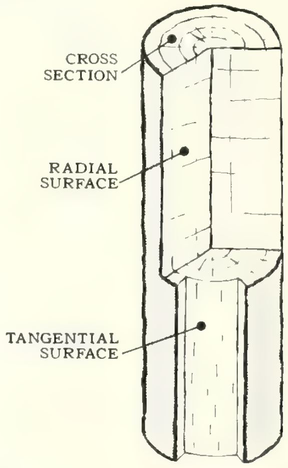
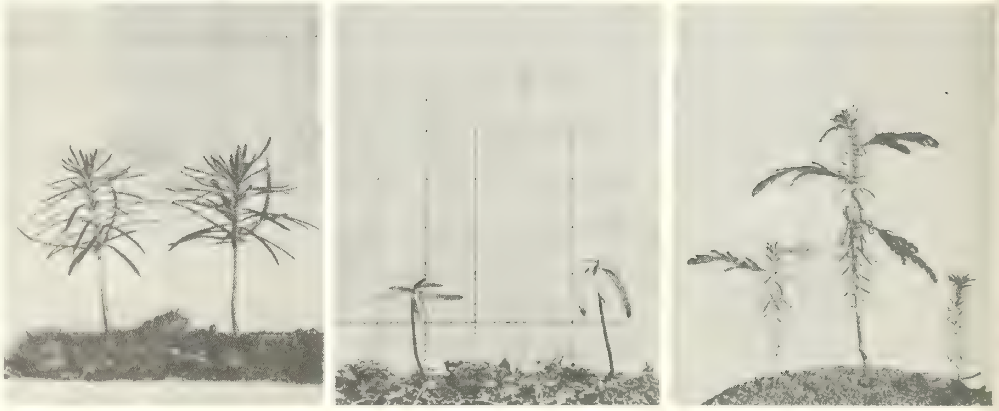


Diagram of cutting planes. Annual rings appear as straight lines on a radial surface. On a tangential surface, annual rings are not evident.

A Guide to Seedling Identification for 25 Conifers of the Pacific Northwest, by Jerry F. Franklin (2)

Identification of very young seedlings of Pacific Northwest conifers has been difficult because they often occur in mixture in forest stands. In addition, descriptions of seedling characteristics previously available are scattered, incomplete, and in some cases, inaccurate.

This is a guide for the identification of young seedlings. It consists of a key to the seeding characteristics of 25 important conifers of the Pacific Northwest. Supplemental descriptions and photos are also provided. The key and descriptions are based on the characteristics of very young seedlings—that is, from the time seedcoats are initially shed until either (1) cotyledons are shed, or (2) the second season of growth starts.



Shasta red fir *Pacific yew* *Western redcedar*

At the end of the first growing season.

Key to Important Woody Plants of Eastern Oregon and Washington, by Doris W. Hayes and George A. Garrison (4)

Winter, spring, summer, and fall, big-game biologists, forest rangers, hunters, and recreationists are on the mountain trails of eastern Oregon and Washington. A knowledge of browse plants, numerous in this region, is increasingly important. This key represents an attempt to meet the demand for a shrub key based on twig or leaf characters and prepared in laymen's language.

Scientific or Latin names are given for each species in addition to common names. Most species are listed, but a few (for example, some of the less common willows) have been omitted on purpose. Also, botanists have not explored all of the Okanogan highlands, the Blue Mountains, and the east slope of the Cascades, so some shrubs found there may be missing in this key.

For standard information on these plants, the reader may also refer to the following:

Abrams, Leroy. *Illustrated Flora of the Pacific States.* (Three volumes.)

Gilkey, Helen. *Handbook of Northwest Flowering Plants.*

Hitchcock, Cronquist, Owenbey, and Thompson. *Vascular Plants of the Pacific Northwest.* A five-volume (very expensive) edition that has now been shortened into a single volume (less expensive).

Hitchcock, C. Leo, and Arthur Cronquist, *Flora of the Pacific Northwest, an illustrated manual.*

White Alder (detail)

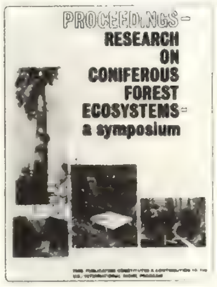
research

Early Stages of Plant Succession Following Logging and Burning in the Western Cascades of Oregon, by C.T. Dyrness (5)

What are the ecological changes that occur following logging and burning in the western Cascades of Oregon? This study, conducted in the H.J. Andrews Experimental Forest, may help foresters make decisions about timber harvesting.

The degree of disturbance from logging and burning apparently has a strong influence on successional trends. In places where the soil was undisturbed, species such as *Acer circinatum, Oxalis oregana,* and *Gaultheira shallon* dominated. Areas disturbed by logging, but unburned, supported a wide variety of both residual and invader species. Light to severely burned sites were mainly occupied by brush or herbaceous species such as *Ceanothus velutinus, Epilobium angustifolium,* and *E. paniculatum.*

Recovery of the preexisting vegetation following logging was fairly rapid. Of the species common to the sites prior to logging, only 13 percent had not come back 5 years after logging.



PROCEEDINGS–
RESEARCH
ON
CONIFEROUS
FOREST
ECOSYSTEMS–
a symposium

Proceedings—Research on Coniferous Forest Ecosystems — A Symposium (6)

This volume, 322 pages, contains the Proceedings of a symposium: "Research on Coniferous Forest Ecosystems: First Year Progress in the Coniferous Forest Biome, US/IBP."

The research program organized under the Coniferous Forest Biome is probably the largest and most comprehensive single effort at ecosystem analysis being carried out in the Western United States. Despite its youthful state there is great interest among ecologists both within and beyond the Biome "boundaries" in the conceptual basis for the Biome's program and present and planned research.

This symposium highlights the concepts and plans underlying major segments of the Biome program and the numerous new insights, techniques, and data which are resulting from the varied research activities.

AN INSIGHT TO "INSIGHTS"

Scattered throughout this publication are a series of feature articles. These have previously appeared in a national, regional, or local magazine or newspaper. These articles, called "insights," deal with specific aspects of PNW research programs in Oregon, Washington, and Alaska. The articles do not present a comprehensive picture of the scope of PNW's research programs, but they are individual titles in a mosaic of all of the possible stories which could be written about PNW research. That would fill volumes larger than this one.

The articles are printed in italic type and are found in the right-hand column of odd numbered pages. Just follow the tracks and have a pleasant and informative trip.

THE MOOSE AND THE HARE

by Thomas Michael Baugh

Aesop may have missed one of the best animal stories of all time by limiting his travels to Greece. If the venerable sage had wandered north and west a few thousand miles, he would have found himself in the interior of Alaska. Being observant, Aesop might have noted an interesting relationship between two four-footed animals of the far north. If so, the opening line of his fable might have gone something like this: "Once there was a moose and a hare, and they both loved the willow."

During the summer, the moose and the hare have little in common. Food appears to be plentiful and the two species have different summer diets. The picture changes in the winter months in areas which have been burned by wildfire and which have a high snowshoe hare population. Food is less abundant and as the snow begins to pile up both of these animals turn to willow shrubs and other hardwoods in order to survive.

Forest Service biologist Jerry Wolff of the Institute of Northern Forestry in Fairbanks, Alaska, began to study the food habits of moose and snowshoe hares following a forest fire which occurred near Fairbanks in 1971. Jerry points out that "in Alaska, fire is the main disturbance which creates new habitats." In fact, browse, including willow, is much more plentiful for moose in the open areas which result from wildfire.

Willow is a hardy shrub which has the ability to withstand heavy browse damage and still grow succulent new shoots each spring. It also has the ability to regenerate quickly in the first few years following a fire. Moose are attracted to the brushy hardwoods and

plant communities

A CLASSIFICATION OF FOREST ENVIRONMENTS IN THE SOUTH UMPQUA BASIN

DON MINORE

A Classification of Forest Environments in the South Umpqua Basin, by Don Minore (7)

A classification of forest environments is necessary in order to get optimum results from forest management practices.

This classification of forest environments in the South Umpqua basin is based upon species' presence and the measurement or estimation of five environmental factors that are basic to plant growth: elevation, temperature, moisture, solar radiation, and soil type.

The classification is a first step—a tool to be used in further work. Silvicultural prescriptions should be tried and evaluated for each environment. In this way, a catalog of successful and unsuccessful treatments will be available for each environmental class.

Psoralea physodes

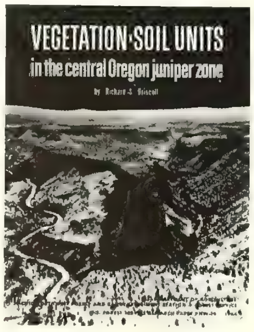
Oxalis

Vegetation-Soil Units in the Central Oregon Juniper Zone, by Richard S. Driscoll (8)

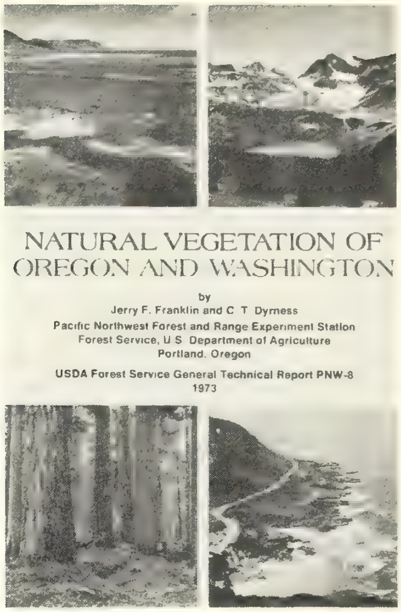
The central Oregon juniper zone includes approximately 108,000 acres in Crook, Deschutes, and Jefferson Counties where western juniper is a major component of the vegetation. This area is one of three physiographic subdivisions of the Northwest representative of the pinyon-juniper zone in the Western United States. Although no pinyon pines occur in the Oregon area, other features are similar to the broad parent zone. The climate is characterized by high summer temperatures, cool winters, high winds, low relative humidity, and low annual precipitation. In the study area, the zone grades to the ponderosa pine zone, where moisture is more effective, and to the sagebrush or grassland zones of less effective moisture.

Juniper zone

The juniper zone has three physiographic subdivisions based on soil parent materials. One of these—the country around Redmond and Prineville—was studied here. In this area, soils are derived from wind-laid and mixed igneous and pumice sands or, where these materials do not comprise the actual parent material, pumice is scattered throughout the soil profile. The pumice probably originated from Mount Mazama (site of Crater Lake), 100 miles southwest of Bend, when the volcano exploded approximately 8,000 years ago. Some pumice may have originated from more recent eruptions of Newberry Crater (site of Paulina and East Lakes), located 25 miles south of Bend. The igneous sands, mostly from andesite, rhyolite, or basalt, were transported from dry lakebeds by southwesterly winds.



VEGETATION·SOIL UNITS in the central Oregon juniper zone



NATURAL VEGETATION OF OREGON AND WASHINGTON

by
Jerry F. Franklin and C. T. Dyrness
Pacific Northwest Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture
Portland, Oregon

USDA Forest Service General Technical Report PNW-8
1973

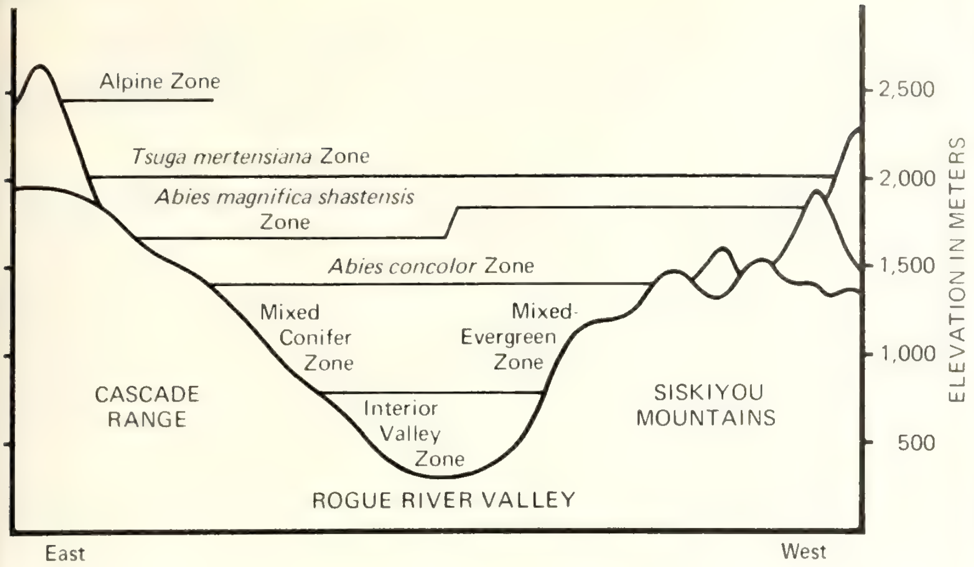
Natural Vegetation of Oregon and Washington, by Jerry F. Franklin and C.T. Dyrness (9)

A major work (417 pages) describing the major vegetational units of Oregon and Washington and their environmental relationships. Descriptions of each vegetation zone include composition and succession, as well as plant variations associated with environmental differences.

Available for sale only ($4.65) from the Superintendent of Documents, Book Store, Room 1056, Federal Office Bldg., 909 First Avenue, Seattle, Wash. 98104. Order by Stock Number 0101-00329.

See also *A Preliminary Classification of Forest Communities in the Central Portion of the Western Cascades in Oregon,* by C.T. Dyrness, J.F. Franklin, and W.H. Moir (10). It describes the characteristics of 23 forest communities and relationships among them. Obtain through PACFORNET or regional libraries.

Jerry Franklin



Arrangement of vegetation zones in the Cascade Range and western Siskiyou Mountains of southwestern Oregon.

Abies magnifica shastensis

Abies amabilis *zone*

Pinus albicaulis

Mudflows are common features near the major volcanoes in the Cascade Range. This mudflow, at Kautz Creek (near Mount Rainier, Washington), occurred in 1947, burying and killing the original forest.

spend the winter cropping the shoots and branches produced during the growing season. Research has found that willow is a necessary component of the taiga, or sub-arctic forest, ecosystem. In discussing the food used by the plant-eating mammals, or "primary consumers," Jerry says that, ". . . willow is probably the most important with respect to primary consumers such as moose and hares."

Normally, snowshoe hares are at home in denser cover than that provided by willow in burned-over areas. Perhaps they feel exposed to predators such as hawks, owls, and lynx. They prefer the mature spruce or mixed deciduous forests which provide both food and cover. During low population times, snowshoe hares "were found only in the densest spruce and mature willow stands," Jerry indicates.

This situation changes when the snowshoe hare populations increase to a high point in their population cycle. This was the case on the burned land north of Fairbanks during the two winters between 1971 and 1973. Because of high numbers the hares ate themselves out of hearth and home. They were forced to move from the areas of high tree density into the burned area. The moose were thus joined by the hares at the free lunch provided by the prolific willow. On occasion, browsing was so heavy that the willows were girdled near the bottom of the stems where the hares were feeding.

How did all of this browsing and gnawing affect the willows? Jerry has found that in order to grow, plants must be able to respond positively to continuous browse damage. Willows are apparently well adapted for this task. They are able to recover each growing season from the previous winter's clipping. In addition, willow growth in burned areas is significantly higher than growth in unburned areas. This is due to lack of competition from other plants and additional soil nutrients. Browsed branches provide almost twice as much new growth each season as their unbrowsed counterparts.

The process cannot go on forever. Willow can withstand heavy browsing for more than 10 consecutive years, but after that the growth rate will decrease. Nature provides for even this situation. By the time the willow has reached its maximum productivity, forest trees are taking over. The vegetative cover changes to healthy, young forests. However, chances are very good that wildfire has struck someplace else continuing this fascinating cycle of nature in the northern forests.

end

next "insight" page 23

ecosystems, classification–bibliography

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economics

See also: Silviculture

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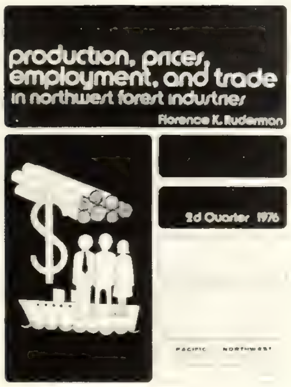
general



production, prices, employment, and trade in northwest forest industries

Florence K. Ruderman

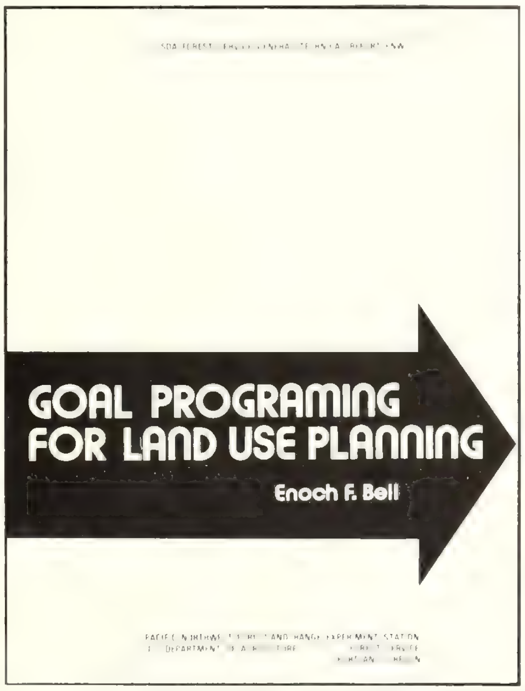
2d Quarter 1976

Production, Prices, Employment, and Trade in Northwest Forest Industries, by Florence K. Ruderman (1)

A quarterly report that presents current nformation on the timber situation in Alaska, Washington, Oregon, California, Montana, Idaho, and British Columbia, ncluding data on lumber and plywood production and prices; timber harvest; employment in forest products industries; international trade in logs, pulpwood, chips, umber, and plywood; volume and average prices of stumpage sold by public agencies; nd other related items.

To Get on the Mailing List:

Ask for the Quarterly Report, and write or all: Paul Barlow, Editorial Services, Pacific Northwest Forest and Range Experiment tation, P.O. Box 3141, Portland, OR 97208. Phone: 503/234-3361, ext. 4924, r FTS: 8-429-4924.



GOAL PROGRAMING FOR LAND USE PLANNING

Enoch F. Bell

Goal Programming for Land Use Planning, by Enoch Bell (2)

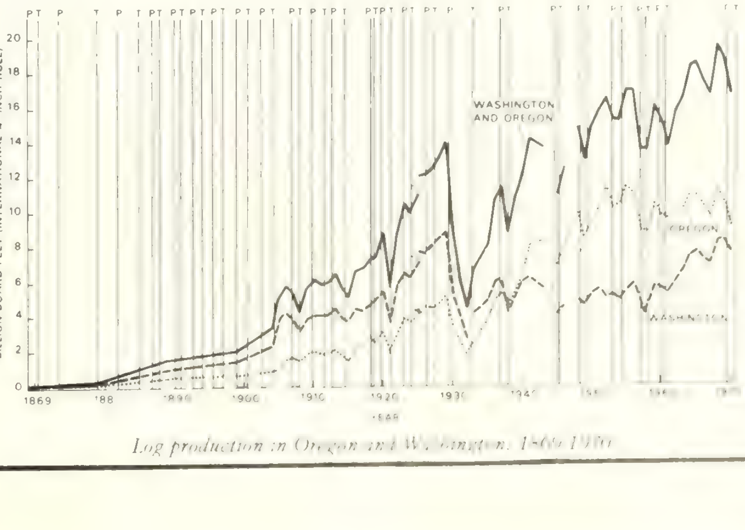
Goal programming has generated considerable interest as a tool for land use planning in multiple goal situations. It does present problems in terms of somewhat difficult data requirements—linearity in its usual form, possible inferior solutions, and lack of explicit recognition of trade-offs. Yet it also presents opportunities for handling complex situations, quickly portraying alternatives, allowing more than one goal, and simulating the "satisficing" decision framework. Goal programming has been used on a few national forests and seems to have provided a useful service to the planners in analyzing their alternatives in these instances. However, it is not a panacea for poor planning and must be used with full recognition of its shortcomings.

timber harvest

Log Production in Washington and Oregon—An Historical Perspective, by Brian R. Wall (3)

The Pacific Northwest Forest and Range Experiment Station has collected and published log production data for many years. These data have been of interest to foresters, resource analysts, economists, business and government leaders, legislators, and the academic community. The last comprehensive historical log production data compilation series for Oregon and Washington was published in 1950, covering the period 1925-48 (Moravets 1950). This study updates that report, presenting data by county for 1925-70 and by county and ownership class for the 1949-70 period.

Oregon and Washington combined produce about one-quarter of the Nation's domestic roundwood. In 1970, total log production for the two states amounted to 16.9 billion board feet. The two states reached a combined record annual timber harvest. The long-term trend in timber harvest for the Pacific Northwest has been a rising one since the mid-1800's even though there have been some sharp fluctuations.



Log production in Oregon and Washington: 1869-1970

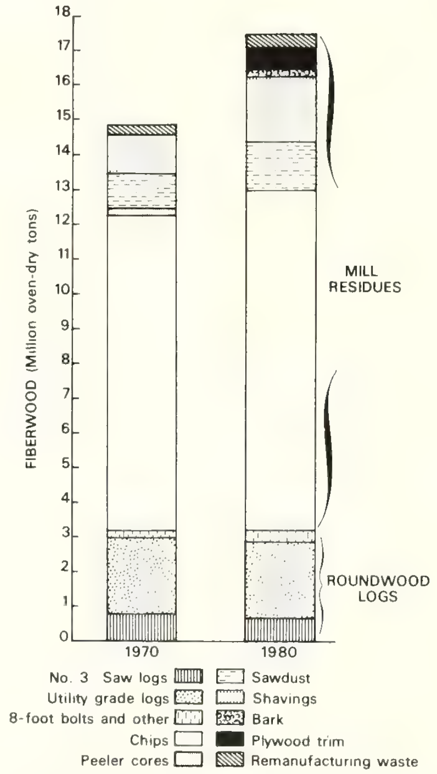
Relationship of Log Production in Oregon and Washington to Economic Conditions, by Brian R. Wall (4)

Increasing demand for timber has put upward pressure on log production in Oregon and Washington. Fluctuations in log production result primarily from changes in national demand for wood products. The log production cycle with respect to business conditions has become countercyclical since World War II. During the 1949-69 period, annual changes in housing starts were significantly related to changes in national forest stumpage prices for all species. Annual stumpage price changes were significantly related to annual changes in log production.

Fiberwood Use in Washington, Oregon, and California, 1970-80, by John W. Austin (5)

This report is based on a survey of pulpmills, board mills, and felt mills in Washington, Oregon, and California in 1970 and 1971. Pulpmill capacity is expected to rise 10 percent over 1970 capacity by 1980; particle board capacity will rise by 80 percent; hardboard up 32 percent; and insulation board up 17 percent. Capacity expansion is limited by pollution control requirements and final product market.

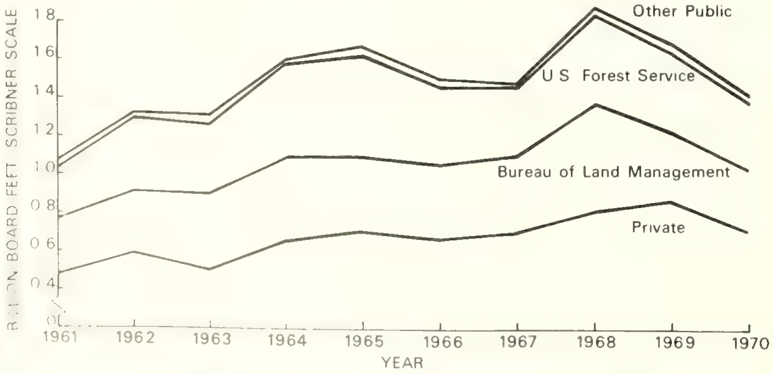
Wood use in these mills is expected to increase 19 percent to 17.7 million ovendry tons per year by 1980. Fiberwood consumption should continue to follow the current pattern, most of the wood coming from sawmill and plywood residues. Under assumptions of declining timber harvest and increasing log exports, lumber and plywood production will also decline, and with it the amount of mill residue available. Pulp and board plants will have to consider alternative sources of material—possibly from thinnings and logging residues.



Current and expected fiberwood use, Washington, Oregon, and California, 1970 and 1980.

Douglas County, Oregon: Potential Economic Impacts of a Changing Timber Resource Base, by David R. Darr and Roger D. Fight (6)

Available projections for Douglas County, Oregon, show that timber harvest from private lands is expected to decline. Forest Service and Bureau of Land Management timber harvest may change over time as priorities and funding change. Identification of the local economic impact of changes in timber harvest is necessary for planning to adjust to projected impacts. An input-output technique was used to estimate for each local sector the impact of the following on sales: Change in demand for forest products; change in Forest Service or Bureau of Land Management appropriations; changes in private, Forest Service, or Bureau of Land Management timber harvest; and a decline in private harvest offset by an increase in Forest Service and Bureau of Land Management harvest. The model used in the analysis can be used to test the effectiveness of new industries, or changes in existing industries, in offsetting projected impacts of changes in timber-oriented industries or agencies.



Douglas County timber harvest by ownership, 1961-70.

Timber Harvest in Oregon and Washington

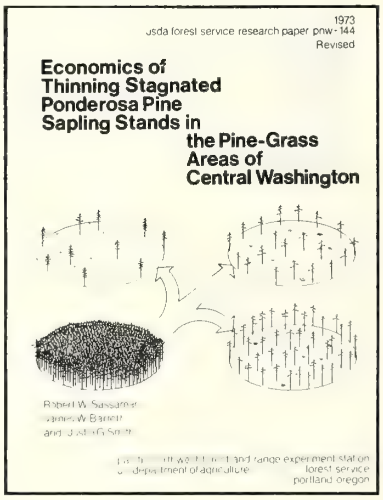
Each year the Experiment Station publishes a resource bulletin outlining timber harvest data for Oregon and Washington. The two-page report shows trends in timber harvest and gives statistics by half state for private, federal, state, and other public lands. When ordering, specify year and state.

thinning

Precommercial Thinning Pays

To thin or not to thin, that is the question. It's all a matter of economics. In this study in the pine-grass region of central Washington, the economics of several treatments were considered: thinning at three stand densities (250, 125, and 62 trees per acre), clearcutting vs. shelterwood cuts, the allowable cut effect, and planting forage to increase economic returns.

In general, economic returns were greatest when the allowable cut effect (ACE) is included, when stands were thinned to 125 trees per acre, in clearcutting rather than shelterwood, and when forage was planted to increase the economic yields.


1973
usda forest service research paper pnw-144
Revised

Economics of
Thinning Stagnated
Ponderosa Pine
Sapling Stands in
the Pine-Grass
Areas of
Central Washington

Robert W. Sassaman
James W. Barrett
and Justin G. Smith

pacific northwest forest and range experiment station
u.s. department of agriculture forest service
portland oregon

Economics of Thinning Stagnated Ponderosa Pine Sapling Stands in the Pine-Grass Areas of Central Washington, by Robert W. Sassaman, James W. Barrett, and Justin G. Smith (7)

Bob Randall

Operations Research and Thinning

An opportunity to save dollars in large thinning projects exists by using an operations research approach. In this study, a mathematical programing technique was used as a base for planning commercial thinning operations. The technique is demonstrated, tested, and compared with other planning methods.

The study utilized information from a Bureau of Land Management special study area of 50,000 acres in western Oregon. The resulting publication provides managers with an improved framework for documenting information, optimizing thinning programs, and testing the consequences of different planning strategies and situations. Although it did not yield dramatic dollar gains in this case, the potential exists for obtaining sizable benefits, particularly in larger, more complex planning situations.

A major obstacle to implementing this approach would be in finding or training qualified people and the initial cost of establishing the system.

An Operations Research Approach to Douglas-fir Thinning, by Robert M. Randall (8)

Economics of Thinning

This study examines four alternative assumptions about the relationship of stumpage price to tree diameter and shows the impact of these assumptions on the financial evaluation of commercial and precommercial thinning in Douglas-fir. The study demonstrates that care should be taken in selecting the price-diameter assumption used to evaluate forest management activities. The results show that not only can the assumption influence the priority of projects selected and the estimates of benefits expected, but that it can be decisive in influencing a project's financial feasibility.

See *Douglas-fir Thinning Values Sensitive to Price-Diameter Relationships,* by Robert M. Randall and David R. Darr (9)

Economics of Forest Range

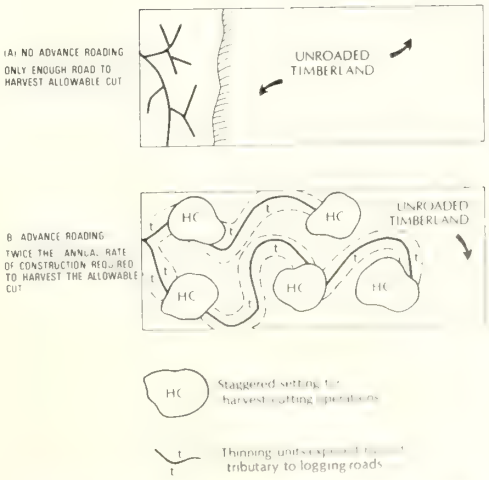
After a decision has been made to precommercially thin a stand of ponderosa pine, it may be advantageous to invest additional funds to increase forage production. Economists have developed a method for figuring the potential rate of investment return in such thinning projects. It is based on the adjusted market value of an Animal Unit Month (AUM) of public grazing and the capital costs of forage production over and above the usual expenses related to thinning.

For details, see *A Tool for Estimating the Financial Returns on Forage Grasses Seeded in Thinned Ponderosa Pine,* by Robert W. Sassaman and Roger D. Fight (10)

road building

An Economic Analysis of Accelerated Road Construction on the Bureau of Land Management's Tillamook Resource Area, by Con H. Schallau (11)

A study was conducted on the Bureau of Land Management's 50,000-acre Tillamook Resource Area to determine the economic feasibility of accelerated roadbuilding. At the time of the study (1970), approximately 5 miles of logging roads were being constructed annually. A plan was proposed to double the rate of road construction to 30 miles per year. Accelerated roadbuilding was found not economically feasible. In fact, investment in such an accelerated program would earn a minus 1.25 percent rate of return. Although advanced roading would increase timber production and timber revenues, the additional revenues would not be enough to compensate for higher maintenance, timber sale administration, and interest charges.


(A) NO ADVANCE ROADING
ONLY ENOUGH ROAD TO HARVEST ALLOWABLE CUT
UNROADED TIMBERLAND
B ADVANCE ROADING
TWICE THE ANNUAL RATE OF CONSTRUCTION REQUIRED TO HARVEST THE ALLOWABLE CUT
UNROADED TIMBERLAND
HC
t
Staggered setting for harvest cutting operations
Thinning units exposed to and tributary to logging roads

Harvesting the annual allowable cut from a continually receding "wall of timber," "A" requires less road construction than "B", advance roading.

PROTECTING WATER SUPPLIES
by Thomas Michael Baugh

Man has been using the forests of the North American continent for thousands of years. This use began with the native peoples, expanded with European colonization, and accelerated with the development of the modern timber industry.

During the past 50 years the focus of forest use has changed from simple logging to total forest management. Part of the management picture involves the use of chemicals to fertilize, protect, or otherwise control the growth of plants in the forest. Chemical use, in this age of heightened environmental awareness, is controversial. The long-term environmental effects of substances such as the herbicide 2,4,5-T are being increasingly questioned.

The PNW Station, through its Forestry Sciences Laboratory in Corvallis, Oregon, is involved in an intensive effort to determine the effects of herbicides, pesticides, and fire retardents on forest environments.

The goals of the program are to provide hard-pressed forest resource managers with guidelines for the safe application of chemicals and to develop a scientific basis for the formulation of environmentally acceptable forest spray policies.

The long-term benefits of this work are not limited to the resource manager. Regulatory agencies need information concerning the environmental effects of chemicals if they are to act in the best interests of the public. The public, itself, will benefit from a safer environment and added protection for our Nation's forests.

Dr. Logan Norris, who heads a chemical behavior and impact research program at the Forestry Sciences Laboratory, believes that "the use of chemicals in modern forestry is increasing in scope and importance along with the sophistication of management and the need to protect and enhance forest values." Norris feels that the use of chemicals will continue to grow in importance as "land managers are faced with a steadily increasing demand for all forest products . . . from a steadily decreasing amount of land."

Chemicals are presently used for a variety of purposes in managed forest ecosystems. DDT is one of the more obvious examples of a chemical whose use became necessary

Who Says Accelerated Roadbuilding Pays? by Con H. Schallau (12)

Accelerated road construction is uneconomical for public timber production units in the Douglas-fir region of Oregon and Washington.

That conclusion is based on a study of three accelerated roadbuilding programs. In one of those areas, on the 50,000-acre Tillamook Resource Area, the financial return dropped from 0.8 percent when 15 miles of road were constructed per year to 0.3 percent when 30 miles of road were constructed.

The author says that recommendations 30, 33, and 36, calling for accelerated road construction and maximum net returns to the Federal Treasury, are inconsistent.

Accelerated Roadbuilding on the North Umpqua—An Economic Analysis, by Brian R. Payne (13)

Accelerated roadbuilding was found to be economically unjustifiable on an old-growth unit of the Umpqua National Forest in Oregon. An important benefit of faster roadbuilding is the earlier removal of both salvable dead timber and current mortality. Although this would have increased the projected annual timber harvest on the North Umpqua unit, the economic gain is negligible. The study reports that the rates of financial return increase by only about one-tenth of 1 percent for four accelerated road construction alternatives considered in the study.

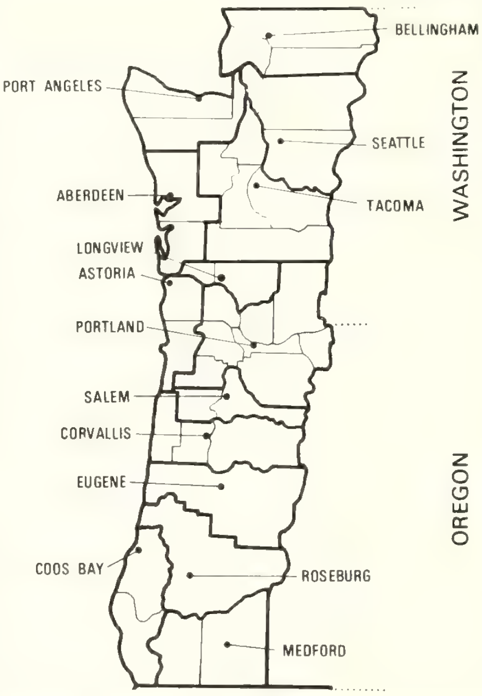
employment

Employment Implications of Projected Timber Output in the Douglas-fir Region, 1970-2000, by Brian R. Wall (14)

The demand for timber in the United States is increasing. Under present levels of timber management, the timber products output in the Douglas-fir region is expected to decline by the year 2000. Based on this projection and on a changing forest industry and increased labor productivity, employment in the timber-based industries in the Douglas-fir region is projected to drop 45 percent between 1970 and the year 2000. Employment-wood consumption relationships are a major factor influencing employment projections, although declining timber products output and a high level of log exports are also important.

Importance of Timber-Based Employment to the Douglas-fir Region, 1959 to 1971, by Wilbur R. Maki and Dennis L. Schweitzer (15)

Even though there were substantial increases in total employment in the Douglas-fir region from 1959-1971, employment in timber-dependent industries declined slightly. Only three of the 14 economic areas in the region matched national employment gains in these industries. Although economies that were highly dependent upon timber in 1959 still were in 1971, in nearly every instance a smaller proportion of economic base employment was concentrated in the timber-dependent industries.



Economic areas and growth centers in Douglas-fir region of Oregon and Washington

A Technique and Relationships for Projections of Employment in the Pacific Coast Forest Products Industries, by Brian R. Wall and Daniel D. Oswald (16)

The purpose of this paper is to provide local and regional planners, public officials, labor representatives, and others with information and a method to help translate future levels of timber supply and wood use by industries into future levels of direct forest industrial employment in Washington, Oregon, and California.

The paper has three major sections: (a) gives equations for estimating future employment in the primary wood-using industries, (b) presents recent trends in total employment as a background against which to evaluate and adjust projections based on wood industry alone, and (c) the seasonal variations of forest industry employment.

stumpage and log value

Log Prices in Western Washington and Northwestern Oregon, 1963-73, by Thomas C. Adams (17)

Average log prices are reported for seven principal timber species of western Washington and northwestern Oregon, for the years 1963-73. For water and inland sales, these prices rose from 86.8 to 232.6 percent over this period; and for export sales, from 361.0 to 732.0 percent.

The U.S. wholesale price index during this period rose 43.4 percent for lumber and 125.0 percent for all commodities.

STUMPAGE PRICE RESPONSES

Stumpage Price Responses to Change in Volume of Timber Sold, by Thoma E. Hamilton (18)

Stumpage prices on timber from nationa forests in the Douglas-fir region have show a long-term increasing trend which is expected to continue until the mid-1980's. I the short term, stumpage prices have fluctuated considerably. An examination of th region's stumpage market indicates tha shifts in demand for wood products, rathe than changes in the quantity of stumpag offered for sale, are the primary determinant of these short-term price fluctuations.

Brian Wall

Stumpage Price—Does It Vary by Tree Diameter? by David R. Darr (19)

This study shows that the relationship between stumpage price and tree diameter tends to vary between areas, and over time for a given area. Relative importance of tree diameter in explaining stumpage price variation tends to decrease when tree diameters are greater than 20 inches. Cost-reducing processes are being adopted by firms for small-diameter timber. As these new processes are adopted, small-diameter stumpage prices in the area should increase relative to large-diameter stumpage prices.

VALUE FOR
SMALL DIAMETER
STUMPAGE
AFFECTED BY PRODUCT PRICES,
PROCESSING EQUIPMENT, AND
VOLUME MEASUREMENT

DAVID R DARR AND THOMAS D FAHEY

Value for Small Diameter Stumpage Affected by Product Prices, Processing Equipment, and Volume Measurement, by David R. Darr and Thomas D. Fahey (20)

Factors that affect the stumpage price for small diameter timber can affect utilization and land management options for this stumpage. Type of milling process and method of lumber pricing and log volume determination were found to have potential for affecting price of small diameter stumpage. The study shows that a Chip-N-Saw operator could pay up to $15.40 per thousand board feet, Scribner scale, more for stumpage than could a band mill sawing similar products. Standard and better lumber pricing rather than pricing by individual grade reduced the margin available to bid for stumpage. Scribner scale consistently had less volume than International scale. Cubic volume measurements were in all cases more precise as predictors of lumber tally than either International or Scribner scale. Relating log diameter to recovery factor consistently improved the accuracy of the prediction. This was true for both Forest Service and Scaling Bureau measurements. These factors should be considered by the land manager and timber purchaser when they evaluate management options sensitive to stumpage price.

Douglas-fir Thinning Values Sensitive to Price-Diameter Relationships, by Robert M. Randall and David R. Darr (21)

Assumptions about the price-diameter relationship of small logs can be important in setting priorities among projects and determining the financial feasibility of commercial and precommercial thinning operations. This paper shows how present value can be influenced by any one of four alternative assumptions about price-diameter relationships, thus influencing decisions about thinning Douglas-fir.

Timber Value—A Matter of Choice, A Study of How End Use Assumptions Affect Timber Values, by John H. Beuter (22)

The relationship between estimated timber values and actual timber prices is discussed. Timber values are related to how, where, and when the timber is used. An analysis demonstrates the relative values of a typical Douglas-fir stand under assumptions about timber use.

Lumber Potential for Cull Logs in the Pacific Northwest, by Thomas A. Snellgrove and David R. Darr (23)

Cull logs are currently used by the lumber, veneer, and pulp industries in Washington and Oregon. Cull log volume left after logging in western Washington and western Oregon amounts to, at most, 10 percent of the log volume consumed by the lumber industry in the two states. However, the potential for increased use of cull logs in the lumber industry is constrained by cyclic variations in product prices.

The potential for increased lumber production from West Coast Douglas-fir cull logs can be used in stretching timber supplies and reducing logging residue. Even though about 47 percent of the gross cubic volume of cull logs could be manufactured into lumber, the lumber produced would be in low grades.

The authors conclude from this study that the economic feasibility of using cull logs for lumber manufacture is marginal except in times of extremely high lumber prices. Lumber price cycles, and similar cycles in prices of products of pulp and plywood industries which compete for the cull log raw material, tend to work against development of lumber processing capacity and residue reduction programs designed specifically for cull logs.

during the most recent outbreak of the Douglas-fir tussock moth. Because of the controversial nature of DDT, the group headed by Norris is testing other substances with insect control possibilities, and evaluating their effects on the environment.

The control of forest insect pests is only a part of the broad picture of the use of chemicals. The common use of 2,4-D, amitrole, 2,4,5-T, and picloram in chemical brush control have given rise to concern about their impact on organisms in brush control areas. Part of the research program at the Forestry Sciences Laboratory has been to assess the probability of the toxic effects these herbicides might have in various fish, birds, and animals.

Norris points out that two factors determine the degree of toxic hazard posed by herbicide use. These are: the toxicity of the chemical and the likelihood that non-target organisms will be exposed to toxic doses. He says that a long history of field use and research experience indicates that the "common brush control chemicals can be used with a minimum hazard to the quality of our environment" and to non-target organisms.

Resource managers are particularly concerned about the effects of chemicals in forest streams. Stream water is the habitat for many biological communities and is a critical commodity for man and other downstream users. In extensive tests conducted throughout Oregon, researchers have found some herbicide residue in nearly all streams which run through or adjacent to treated areas. While the highest concentrations occurred shortly after application, they never exceeded 0.1 ppm and persisted for only a few hours. The greatest probability of stream contamination occurs through the direct application of chemicals to the water, either by the intentional inclusion of streams in spray areas or drift of spray material from nearby areas. Norris feels these are planning and application problems which can be easily avoided. He says, ". . . if you don't want chemicals in the water, then don't put them there."

Although the picture for herbicide use is bright, there are several factors which should be carefully considered. The direct application of herbicides to marshy areas can lead to high-level, persistent concentrations of chemicals in nearby streams. Norris cautions that "special care must be taken to avoid treatment of such areas." To date, research has found that another possible problem, chemical leaching throughout the soil,

Potential Responses of Softwood Markets to the Monongahela Decision, by Darius Adams and others (24)

The authors describe the potential effects that a nationwide application of the Monongahela decision would have on softwood stumpage prices, timber harvest levels, lumber and plywood production and prices, and imports of softwood lumber from Canada. The effects are estimated for the period 1980-2000 by use of a simulation model.

Nationwide application of the Monongahela decision would reduce national forest harvests and cause U.S. lumber and plywood prices to rise 15 to 20 percent more over the next two decades than would be expected under current timber flow policy. Softwood stumpage prices would increase 35 to 45 percent over the same period.

Price effects of the reduction in national forest output would be partly offset by increased harvest on private lands and increased imports of lumber from Canada. Stumpage prices would increase most on the West Coast, accentuating the trend toward concentration of lumber and plywood production in the South.

log exports

Log Exports Summarized

Each month research economist Dave Darr gathers together the available statistics on log exports and prepares a press release that gives export statistics for Oregon, Washington, northern California, and Alaska. Information in the report includes the volume of shipments and their value.

To get on the mailing list, write: Information Services, U.S. Forest Service, P.O. Box 3141, Portland, OR 97208.

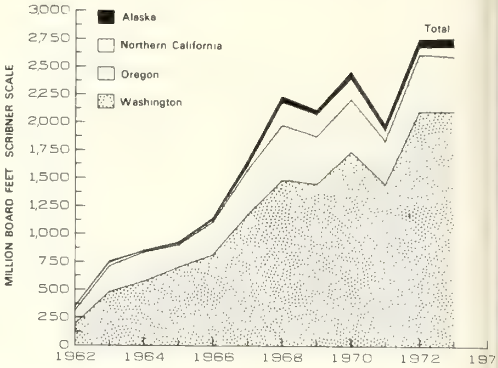
Dave Darr

Softwood Log Exports and the Value and Employment Issues, by David R. Darr (25)

The value and employment trade-offs involved in exporting versus logs domestic manufacture are only part of the broader debate over softwood log exports.

Direct employment per thousand board feet of logs processed in Washington and Oregon in 1973 was 4.72 man-hours for the log export industry, 12.58 for the lumber industry, and 19.47 for the veneer and plywood industry.

Relative export values were higher in 1970 and 1973; domestic values were higher in other years over the period 1965-73.



Softwood log exports from the Alaska, northern California, Oregon, and Washington Customs Districts, 1962-73.

The Morse Amendment and Federal Timber Sales, by John W. Austin (26)

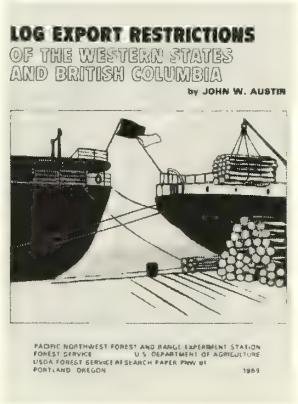
Log export from the West Coast has been a heated issue for several years. In recognition of this, Part IV of the Foreign Assistance Ace of 1968 (Morse Amendment) limited log exports from federal lands west of 100th meridian to not more than 350 million board feet. This amendment was due to expire on December 31, 1971, but the Housing and Urban Development Act of 1970 extended the export restrictions through 1973. This article provides some insight into how the Morse Amendment has been applied to U.S. Forest Service and Bureau of Land Management lands, and how it has been affecting the export of federal timber.

The Jones Act and the Douglas-fir Region Softwood Lumber Industry in Perspective, by John W. Austin and David R. Darr (27)

Because of the Jones Act, foreign flagships cannot be used for intercoastal shipment of lumber in the United States. As a result, British Columbia producers have a transportation cost advantage in competing with west coast U.S. producers for east coast markets. In the context of the total competitive environment between the two areas, however, other factors—especially stumpage price differences—may override this advantage. If exempted from the Jones Act, Pacific Northwest softwood producers would have to prepare for assemly of cargo and development of east coast markets to take full advantage of lower-cost foreign flag vessels. Evaluation of the impact of the Jones Act should be within the context of the Act's objectives, the need for waterborne as opposed to other transportation modes, and the market forces which determine competition with British Columbia.

Log Export Policy: Theory vs. Reality, by Thomas E. Hamilton (28)

A good, short summary of some of the issues and policies involved in the log export question, a situation too complex to summarize quickly. Hamilton indicates in summary that our policies should be directed toward long-term achievement of whatever goals are deemed most important, an approach that would prevent short-term actions undertaken only after a problem has become serious.



LOG EXPORT RESTRICTIONS
OF THE WESTERN STATES
AND BRITISH COLUMBIA
by JOHN W. AUSTIN

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
USDA FOREST SERVICE RESEARCH PAPER PNW 81
PORTLAND OREGON 1969

Log Export Restrictions of the Wester States and British Columbia, by Joh W. Austin (29)

The volume of logs exported from th Pacific Northwest has been widely publicize in the past few years. These exports, wit the strong domestic market for wood prod ucts, have resulted in increasing demand on the Pacific Northwest's timber resources In response to these pressures, various lo export restrictions and primary manufactur ing requirements for timber products hav been proposed and enacted. This paper pre sents the main provisions of these expor restrictions.

Price Impacts of Log Export Restrictions Under Alternative Assumptions, by Richard W. Haynes (30)

What effect would a ban on log exports have on the price of softwood lumber and stumpage? The answer to that question is explored n a 1976 report, given various assumptions about the market for softwood lumber. The author says that following a ban on log exports, western softwood lumber prices would either decrease as much as 16 percent or increase by as much as 17 percent depending on the direction of the supply shift.

The equivalent changes in the stumpage market would be 26 and 29 percent, respectively.

U.S. Forest Products Trade Policies: What are the Options? by David R. Darr (31)

Analysis of U.S. trade policy necessarily involves many sensitive issues. The author's evaluation of these issues may not correspond with U.S. Forest Service or other federal policy. The author has prepared this paper because of the wide interest in the subject matter. It is intended for use as a background report and should interest members of the forest products industries and others who are affected by forest products trade policies.

Trade and other policies are being considered by the U.S. Forest Service according to the terms of the Forest and Rangeland Renewable Resources Planning Act of 1974. This paper describes the issues involved in the question, "Should we or should we not attempt to reduce net imports of forest products?" There is no clear rationale, either in theory or in existing U.S. trade policy, for balancing imports and exports of a commodity.

In terms of volume, net imports of forest products amount to about 12 percent of U.S. consumption. The value of imports exceeds the value of exports by about $1.5 billion. Most of U.S. softwood imports come from Canada and hardwoods from South Korea, Taiwan, Japan, and the Philippines. Japan and the Common Market countries are the major markets for U.S. forest products exports.

Without a change in trade policy, net imports of forest products may increase. Constraints on options for increasing exports or decreasing imports limit the feasibility of policies designed to change existing and expected trade patterns.

The author suggests that policies should be weighed in terms of their effects on both international and domestic goals. Most effects of changes in either import or export policies would be due to increases in the relative prices of forest products.

allowable cuts

Sensitivity of Allowable Cuts to Intensive Management, by Roger D. Fight and Dennis L. Schweitzer (32)

The Forest Service and the Bureau of Land Management are both using some form of even flow management to establish timber harvesting programs. These agencies are faced with several questions about the effects of growth-stimulating treatments, such as precommercial thinning, on the even flow production of timber resources.

The four most pressing considerations are: (a) How will the allowable cut be changed by growth-stimulating treatments? (b) Will the change in allowable cut equal the change in annual growth attributable to the treatment? (c) Will the cut continue to change in proportion to changes in annual growth as these successive changes are made? (e.g., as fertilization and genetics are added to precommercial and commercial thinning), and (d) How are answers to these questions affected by the volume and age-class distribution of initial inventory?

PNW researchers Roger Fight and Dennis Schweitzer evaluated regeneration periods, thinning yield, genetic improvement, fertilization, and changes in base acreage against the questions listed above in order to determine the effect on allowable cut.

In general, the results of the study indicate that allowable cut responds more to changes in long-term growth where there is a high initial inventory that can support a level of harvest above the growth in merchantable stands for a long period during which growth is building up.

This is just one of six conclusions reached in the report. The implications of this kind of research on long range resource management make this study a reading must for those involved in planning large-scale timber harvest programs.

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is a slow process which only moves small amounts of chemicals short distances through the ecosystem. In addition, overland flow seldom occurs. Most of the herbicide which is applied eventually enters the forest floor where microorganisms degrade the herbicides to harmless material in a short time.

Fertilization is another chemical use which is increasing rapidly on forested lands. Dr. Duane Moore, a colleague of Norris, points out that between 1963 and 1969, over 90,000 acres were fertilized in western Oregon and Washington. This increased to 100,000 acres a year by 1971 and the rate continues to climb. Fertilization contributes to increased growth rates helping to meet the demand for wood fiber.

Are we involved in a trade-off between increased wood fiber and decreased water quality? This question was studied on the South Umpqua Experimental Forest in southwestern Oregon and at 28 other sites in western Oregon and Washington which have received urea fertilizers.

Moore reports that these applications have not resulted in toxic chemical levels during the first year following treatment. It's important to note that all of the fertilizer levels measured by Moore in forest streams were well within the limits established as acceptable for human consumption. The information presently available is only preliminary and does not answer all the questions. Moore says that "more complete information is needed on the effects of forest fertilization on the total nitrogen budget, mobilization, movement, and nutrient cycling before we can totally define the nature and extent of the impact of fertilizer on the forest environment."

The necessity for managed forests will increase as the demand for wood fiber and other forest products increases. It's safe to assume that the number of acres treated with chemicals will continue to grow. At the same time, the public has a right to know that the treatment of forest environments will not violate public health standards and create health hazards. The research of the Managed Forests Watershed Unit at the Forestry Sciences Laboratory is contributing to the knowledge necessary to meet forest products demand and insure a healthy environment.

end

next "insight" page 31

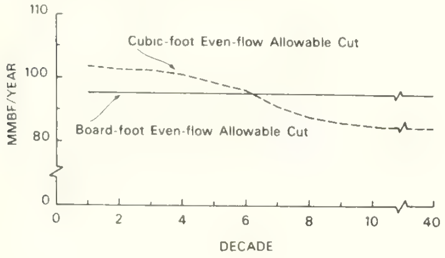
ACE, The Two-Edged Sword, by Enoch Bell, Roger Fight, and Robert Randall (33)

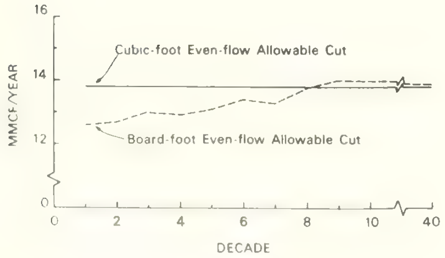
The potential for misusing ACE by applying it selectively for only one type of investment was recognized by PNW researchers Enoch Bell, Roger Fight, and Robert Randall. They demonstrated that ACE can sometimes drastically reduce the value of benefits especially those associated with fire, insect, and disease protection of old-growth inventories. They conclude that if ACE is used by an agency for evaluating investments of one type then it must be used for all investments. The authors point out that ACE, like the two-edged sword, can cut in both directions.

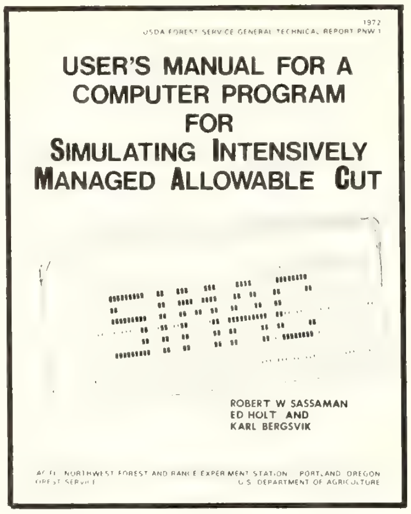
The allowable cut effect is clearly an important issue in forestry. However, its role in forest management and policy decisions is still in dispute.

What If We Calculate the Allowable Cut in Cubic Feet? by Roger D. Fight and Dennis L. Schweitzer (34)

According to PNW researchers, allowable cuts on federal lands are increased when timber harvest levels are computed in cubic feet. PNW researchers Roger Fight and Dennis Schweitzer have found that with smaller trees, we will have to cut more cubic volume in the future than in 1974 to recover an equal volume in board feet. This assumes that cubic-foot volume computations become the standard.






1972
USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-1

USER'S MANUAL FOR A
COMPUTER PROGRAM
FOR
SIMULATING INTENSIVELY
MANAGED ALLOWABLE CUT

SIMAC

ROBERT W SASSAMAN
ED HOLT AND
KARL BERGSVIK

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION PORTLAND OREGON
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

User's Manual for a Computer Program for Simulating Intensively Managed Allowable Cut, by Robert W. Sassaman, Ed Holt, and Karl Bergsvik (35)

This program presents detailed operating instructions for SIMAC, a computerized forest simulation model which calculates the allowable cut assuming volume regulation. for forests with intensively managed stands. A sample program, included in the publication, illustrates the required inputs and expected output.

Uncertainty in Timber Planning

Many people consider forestry a risky enterprise, partly because of the long waiting periods involved. Error in predicting future events is of particular concern when allowable cut levels are set for timber. Most timber planners treat estimates of growth and other factors as if they were known with certainty, but hedge their guesses by frequent replanning, keeping options open.

When plans are revised the cut may be adjusted up or down. If the social cost of a shift in one direction is expected to be greater than the cost of an equal change in the other direction, or if one direction seems more likely than the other, an explicit risk strategy may be appropriate. Some sources of social cost and several risk strategies are described in *Coping With Uncertainty—A Conceptual Approach for Timber Management Planning* by Bell and Fight (36).

Bob Sassaman

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mensuration

See also:
Silviculture
Timber Quality
Alaska

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Background

The title of a popular book asks the question, ''How Do You Spank a Porcupine?'' The answer is, ''Very carefully.'' This same answer applies to the techniques used to measure millions of acres of timber throughout the Pacific Northwest. Timber resources are constantly changing. Old-growth forests are providing timber in increasing amounts, and uses are being found for species previously neglected by the forest products industry.

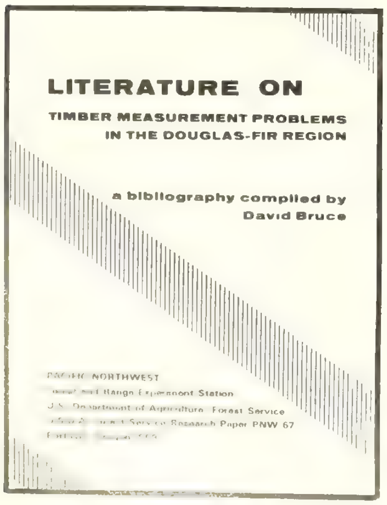
The application of the techniques of computer science has had a profound effect on forest mensuration. The skillful use of computers has made possible the analysis of a large volume of data. Researchers are now able to provide increasingly reliable data on tree growth. This has been used to update older, hand-computed growth and yield tables. Computers have also been used in the development of new mensuration techniques.

PNW researchers have been involved in developing measurement techniques and volume estimates of timber potential for many years. Many of the products of their work—yield tables, volume equations, stem analyses, and log scaling techniques—are documented in this section of the Almanac.

Those who want a quick summary of research on forest mensuration in the Pacific Northwest should obtain a copy of the information leaflet, *Timber Measurement and Management Planning in the Northwest* (1). The objectives of forest mensuration research at the PNW Station include the development of improved techniques for accurately measuring forest trees, the prediction of timber yield through tree growth, the estimation of volume, the diversity of products wood fiber can produce, and the development of forest management plans.

TIMBER MEASUREMENT
AND MANAGEMENT PLANNING
IN THE NORTHWEST

RESEARCH OBJECTIVE


LITERATURE ON
TIMBER MEASUREMENT PROBLEMS
IN THE DOUGLAS-FIR REGION

a bibliography compiled by
David Bruce

PACIFIC NORTHWEST
Forest and Range Experiment Station
U.S. Department of Agriculture Forest Service
Research Paper PNW 67

Literature on Timber Measurement Problems in the Douglas-fir Region,

a bibliography by David Bruce (2)

This 28-page bibliography, published in 1968, was prepared as part of an analysis of measurement problems in the Douglas-fir region of Oregon and Washington. It includes publications on the subject of tree and log measurement, with the exception of taper, volume and yield tables, and some standard forestry texts that made no specific reference to regional measurement problems. It also includes many publications that describe measurement systems or problems elsewhere in the United States and Canada and a few foreign publications that cover subjects not located in the American literature. A subject matter index is included.

Volume & Yield Tables

In 1969, PNW mensurationist Robert O
Curtis stated that the objective of yiel
studies is to predict stand development a
affected by the passage of time, and by sit
and cultural treatment. ''Normal yiel
tables no longer meet our needs. . . . W
need yield tables for managed stands,'' h
said (3). Curtis points to the need for alte
native approaches to the development o
managed stand yield tables based, in part
on measurement of yield over a period o
time.

New publications, with current measure
ment data, are now replacing older volum
tables (4). These studies represent a wid
range of species and span the Pacific North
west and Alaska. Volume equations hav
been published for second-growth Douglas
fir (5); old-growth western redcedar an
Alaska-cedar in southeast Alaska (6); whit
spruce, balsam poplar, and paper birch i
the Kuskokwim River Valley in Alaska (7
and red alder (8).

Studies of timber yield exist for red alde
(9), western hemlock (10), ponderosa pin
(11), different age and stand compositions o
Douglas-fir (12), central Oregon lodgepol
pine (13), and well-stocked white spruc
stands in Alaska (14).

In 1968, David Bruce and Robert W. Cow
lin took an overall look at forest mensura
tion in the Pacific Northwest, in a publica
tion titled, *Timber Measurement Problem*
in the Douglas-fir Region of Washingto
and Oregon (15). The outcome of inter
views and conferences with over 120 fores
managers and timber producers indicate
that a great deal of confusion existed in th
field of forest measurement.

The authors found that the Scribner rule
which assigns little volume to small trees o
logs, is not well adapted to estimating th
value of second-growth stands. In additio
log scaling without taper allowance make
conversions to any other unit of volum
inaccurate.

he researchers also found that the estimaion of grade and defect is based to a large xtent on subjective judgment and that diferent defects reduce yields of various prodcts to different degrees. Most volume estiates for standing trees depend on volume ables that have an undetermined bias and nspecified errors. To compound this probem, the authors state that "When cruising tanding trees, sellers cannot predict accuately the utilization and bucking lengths nd, hence, the probable scale."

ach one of these observations contributes o a picture of confusion which could lead to conomic loss. In summary, the authors tate that the timber industry is faced with ne need for a method to accurately deternine the value of each log for alternative roducts. Such a system is still in the rocess of development.

ollout or yard

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ruck

Log scaling conditions

A Method of Estimation of Gross Yield of Douglas-fir, by Robert O. Curtis (16)

This paper presents a method of estimating gross yield of forest stands and some estimates of gross yield of unmanaged stands of Douglas-fir. It is based on assumptions, techniques, and basic data that differs from those used in previous work.

Possible uses include: (a) comparison of potential yield of alternatives species, (b) indication of yield which may be obtainable with intensive management and nearly complete salvage of mortality, (c) evaluation of effect of variable on the rate of wood production, and (d) comparison of hypothetical management regimes.

The Cubics are Coming: Predicting Product Recovery from Cubic Volume, by Thomas D. Fahey and Richard O. Woodfin, Jr. (17)

If the standard measure for selling timber becomes the cubic foot rather than the board foot, the advantages will far outweigh the inconveniences and a further change to metric units will be facilitated. Much of the published grade-yield and product-recovery information contains cubic volume data that will be very useful in the transition period. The important values are product recovery factor, product recovery ratio, and the relationship of product measure to cubic feet of products recovered. This report defines and shows how to calculate and use these factors.

Forest Survey

The problems of forest mensuration are best observed in the area of forest survey. The data gathered by inventory crews eventually forms the foundation for forest management policy on most levels of ownership. PNW researcher Melvin E. Metcalf said that, "The fundamental objective of the inventory is to provide the information needed to make choices and decisions regarding future policies and programs" (18).

Survey is usually a process of estimation and estimation is subject to error. For this reason, PNW researchers and others are concerned with designing survey methods and mathematical models which will help minimize error (19).

Bob Curtis

THE FOREST AND THE TREES

by Thomas Michael Baugh

Timber covers much of Alaska, from the beautiful offshore islands in the southeast portion of the state through the dense coastal area to the forest of the interior.

Wood from these forests was used by early man for tools, warmth, and dwelling places. It wasn't until the middle part of the present century that industrial consumption began to make significant use of the timber resource.

Early-day forest management has been described as custodial, with an emphasis on forest protection. Little was known about the factors involved in the regeneration and growth of Alaska's forest trees. In 1948, a Forest Research Center was established by the Forest Service at Juneau. Twenty years later the Juneau facility, renamed the Forestry Sciences Laboratory, and the Institute of Northern Forestry at Fairbanks became administrative units of the PNW Station.

In the past 27 years, researchers have made significant progress in understanding the complex worlds of the Alaskan forests. The research picture is by no means complete and perhaps never will be. However, the gaps in a basic understanding of the ecosystem are gradually being filled in.

The key to understanding the forests of Alaska lies in the fact that the coastal forests and the interior forests are two separate worlds. The 13 million forested acres of coastal Alaska are characterized by magnificent stands of Sitka spruce, western and mountain hemlock, western redcedar and Alaska cedar. These forests are extensions of the coastal rain forests of Oregon, Washington, and British Columbia. This is in contrast to the 106 million acres of mixed white and black spruce, paper birch, aspen and balsam poplar found in the interior.

The coastal forests hold about 86 percent of the total commercial sawtimber volume in Alaska, averaging more than 30,000 board feet per acre and ranging anywhere from 8,000 to more than 100,000 board feet. Timber volumes in the interior are lower, with an estimated 22½ billion board feet of commercial sawtimber averaging slightly over 3,000 board feet per acre.

Multiresource Surveys

Traditionally forest survey has dealt with several variables of measurement such as timber volume, growth, etc. The trend today, however, is to the multiresource survey where other forest resources are assessed.

According to PNW researcher John W. Hazard, "The problem then becomes one of how to deal with multipurpose surveys—how to coordinate information needs and how to design the survey to meet these needs efficiently" (20). Hazard proposes a sampling system which will optimize the multiresource inventory and discusses some of the factors which will increase the efficiency and reliability of sampling.

John Hazard

Allocation of Resource Uses

Robert E. Buckman and Roger D. Fight raise a question which is a key to the conflicts which arise when natural resources are allocated through a resource management planning process (21). According to the authors, "The central question around which most major resource conflicts revolve is: Which benefits will be produced? The question of who will receive the benefits and who will pay the costs is seldom raised." The authors feel that this situation develops because "what is produced" largely determines who will benefit. For example, the "production" of wilderness, through the allocation of large tracts of land to the wilderness preservation sysem, will obviously benefit those who use wilderness. According to the authors, resource inventory data must be viewed as just one step in the process of resource decision-making and must be "fully integrated" with other phases of the decision-making process through cooperative efforts with other disciplines.

The debate and concern with the use of inventory data in the management and allocation process will probably continue for some time with each interested party trying to claim a bigger piece of the resource pie. High level resource management decisions, however, will continue to be based, in part, on the data produced in the process of measuring the existing resources.

Research Profile

PNW scientists have completed a wide range of studies in order to provide a better data base for both volume and yield estimates. The publications briefly reviewed below are helping to increase the standardization and reliability of forest mensuration.

Estimating Volume of Douglas-fir Butt Logs, by David Bruce (22)

A new equation to provide a close estimate of the cubic-foot volume of flaring butt logs. This equation takes the guessing out of previous methods by introducing measurements of log length, top diameter inside the bark, and butt diameter inside the bark.

Volume Tables vs. Dendrometers for Forest Surveys, by John W. Hazard and John M. Berger (23)

Volume data measured from trees by using a dendrometer is more reliable than volume data estimated from volume tables which are based on Behre's equation of tree taper.

Considerations and Problems in Determining Volume Growth of Individual Trees, by Donald L. Reukema (24)

This study, based on field research, provides comparisons of the problems encountered with the various measurement systems used to compute tree growth.

Some Transformations of the Behre Equation of Tree Form, by Donald Bruce (25)

Methods of modifying the basic Behre equation for use with various top diameters. A valuable set of formulae for those who have to measure merchantable volumes to top diameters which do not appear in published tables.

Potential Production in Thinned Douglas-fir Plantations, by David Bruce (26)

Each year the number of intensively managed Douglas-fir stands in the Pacific Northwest increases. Intensive management has been practiced in Europe for a much longer period than in North America. This study reviews data gathered from European plantations and demonstrates that major gains in production can be expected from intensive management.

Photo Stratification Improves Northwest Timber Volume Estimates, by Colin D. MacLean (27)

The data from both photo and field plots, when used together, is twice as efficient as simple field sampling in estimating the total timber volume from a forest inventory.

1972
usda forest service research paper pnw-145

PHOTO PLOT BIAS

Robert B. Pope,
Bijan Payandeh,
and David P. Paine

pacific northwest forest and range experiment station portland oregon
u.s. department of agriculture forest service

Photo Plot Bias, by Robert B. Pope, Bijan Payandeh, and David P. Paine (28)

In a study of photo intensity (the number of aerial photos per unit of land surface), researchers found that lands that were primarily nonforest had more photos per unit of area that did forest lands. This may cause a serious source of bias in any forest inventory when photo plots with an equal number of plots per photo were used. This problem can be avoided by transferring plot locations from maps to photos.

3P Sample Log Scaling, by Floyd A. Johnson, James B. Lowrie, and Martin Gohlke (29)

The 3P sample selection procedure was originally developed for timber cruising but has now been applied to log scaling. As used, the scaler quickly guesses the small-end diameter and length of each log in the group of logs in which the estimate of total volume is required. The two estimates are then translated to gross log volume using the Scribner Decimal C log scale. The estimated gross volume is compared with a random number from a specially prepared set of random numbers. If the random number is greater than the guessed gross volume or if the random number is zero, the guess is recorded and the log is passed by. If the random number is less than or equal to the guess, but not zero, the log is carefully scaled for both gross and net volume.

This method looks promising for some scaling situations and may prove less expensive than sample log scaling methods now in use.

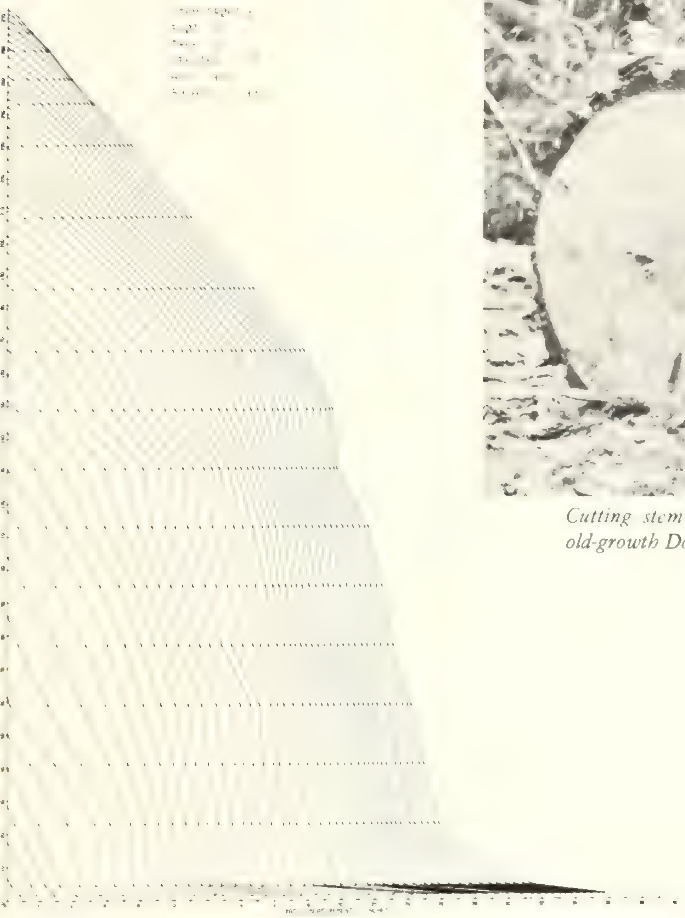
Effect on Diameter Estimates of Rounding Rules in Scaling, by David Bruce and Donald J. DeMars (30)

West of the Cascades, the scaling practice is to drop fractional inches and use the next lower full inch of diameter. East of the Cascades, diameters are scaled to the nearest inch. The difference in the two scaling procedures obviously contributes to a difference in recorded volume. This paper suggests two ways to eliminate the biases introduced by the two systems presently in use.

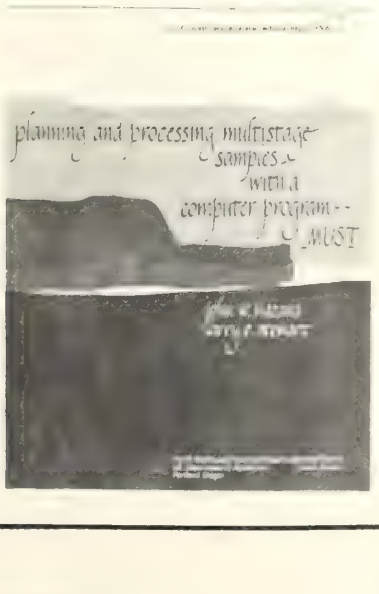
Field and Computer Techniques for Stem Analysis of Coniferous Forest Trees, by Francis R. Herman, Donald J. DeMars, and Robert F. Woollard (31)

A comprehensive publication which describes both field and computer methods of stem analysis. Field instructions include a step-by-step explanation of tree cutting, sectioning, ring count, and measurement techniques. The last half of the publication presents a computer program which calculates the height, age, site, and index, gives instructions for punching this information on cards, and plotting height, age, and stem profile graphs.

Cutting stem section disk from old-growth Douglas-fir.



Computer-produced stem profile chart for noble fir with a breast-height age of 432 years.



planning and processing multistage samples with a computer program -- MUST

Planning and Processing Multistage Samples with a Computer Program —MUST, By John W. Hazard and Larry E. Stewart (32)

Here's a computer program which handles multistage samples up to three stages. The program is based on MUST (multistaged sampling) and provides three different options for the computation of different levels of data.

Part of the reason for this difference lies in the average age of timber stands in the interior and along the coast. The coastal forests are composed of a large volume of old-growth, while the interior forests are much younger, due to frequent summer wildfire. The major difference in sawtimber volume is related to the productivity of the land and this is based on differences in climate and soil.

In general, reforestation in the coastal forests of southeastern Alaska occurs naturally. The process of stand regeneration is well understood. Conifer seedlings which escape logging and seed from nearby trees combine to produce the new stand. The removal of shade from the logged overstory increases ground temperatures, light, and biological soil activity. Researchers have found that the open conditions created by clearcutting favor the growth of Sitka spruce. For this reason, the percentage of spruce seedlings is higher in clearcut areas than in old-growth forests.

Initial growth is relatively slow and it may take up to 10 years for a clearcut to green up. In one experimental area, dominant hemlock averaged 24 feet in height and dominate spruce 15 feet in height within 15 years following logging. Crown closure begins to occur sometime between 15 and 20 years. This is about the time the spruce and hemlock stands begin to reach their maximum growth rate. The volume of wood produced by a normally stocked stand 30 years old is expected to average 3,800 cubic feet of wood per acre. The same stand at age 50 has almost doubled its wood volume to 7,275 cubic feet.

Most researchers agree that for hemlock-spruce stands, clearcutting is the preferred harvest system both from the point of view of silviculture and economic necessity in the high-cost Alaskan economy. Al Harris of the Forestry Sciences Laboratory in Juneau feels that clearcutting will remain the most important silvicultural system in the future but that shelterwood and selection systems will increase in importance in managed stands.

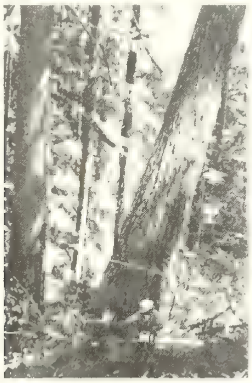
Regeneration is only one of several silvicultural programs currently underway in southeast Alaska. Other studies focus on stand density, wind-throw, and the relationship of logging systems to anadromous fish production and rearing.

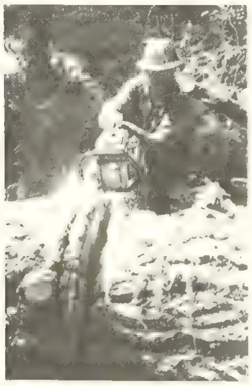
New Trends

Timber cruisers, working for the Bureau of Land Management, are using the fall, buck, and scale (FBS) system to estimate timber volume. This system is explained and analyzed in the September 1972 issue of the *Journal of Forestry* (33).

Under FBS cruising, sample trees are felled and bucked by either contract or hired loggers. The cruisers are under certain restrictions which vary depending on local industry requirements, but otherwise buck to optimize tree value. BLM scalers then tally gross length and diameter for each log along with log grade and defect deductions in terms of length and character.

The FBS system reduces the inaccuracy of timber data caused by cruising standing timber which is subject to breakage and hidden defect.


Falling


Bucking

Scaling

Predicting Wood Volumes for Ponderosa Pine from Outside Bark Measurements, by P.H. Cochran (34)

Since the STX-FORTRAN computer program is widely used, investigators involved in measurements of bark thickness should be aware that perhaps other equations may more accurately describe variations in ratios of the diameter inside of the bark to the diameter outside of the bark along the boles of trees. The author analyzes assumptions and equations in common use and suggests a new approach to enhance accuracy.

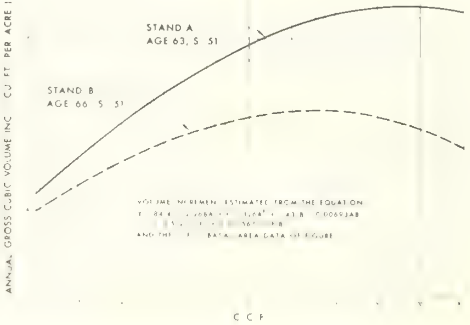
The author states that assumption of a constant diameter inside bark to diameter outside bark ratio along the bole of ponderosa pine results in an underestimate of wood volume determined from optical dendrometer measurements in the STX program. This ratio generally increased up the stem to a given diameter outside bark to diameter breast high outside bark ratio that varies with tree size and then decreases to the tip. Equations describing this change in bark thickness can be incorporated into the STX program. Resulting estimates of diameters inside bark, volume segments, and whole tree volumes are closer to true values than estimates derived by the constant ratio assumption.

Preliminary Site Index Curves for Noble Fir From Stem Analysis Data, by Donald J. DeMars, Francis R. Herman, and John F. Bell (35)

Stem analysis studies are available as background information for managing the upper-slope forest complex. The studies include data for old-growth noble fir as well as other species associated with noble fir. The polymorphic site index curves presented in this report provide reliable estimates of site index for noble fir found between McKenzie Pass in Oregon and the White River drainage of Mount Rainier in Washington.

Relationship of Lodgepole Pine Volume Increment to Crown Competition Factor, Basal Area, and Site Index, by Walter G. Dahms (36)

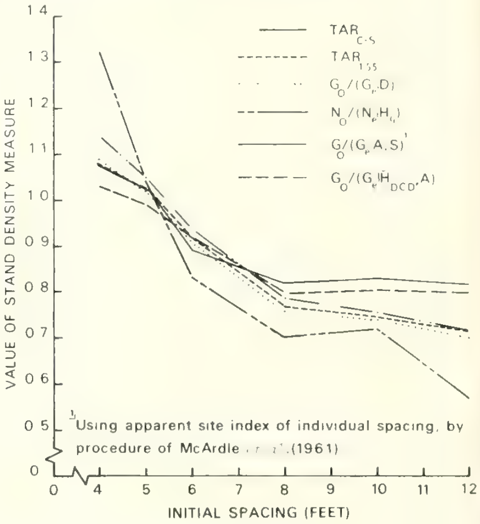
Stand density control may be the forester's most important tool for attaining specific management objectives. In this paper the author discusses the relationship of crown competition factor with the gross cubic foot volume increment for lodgepole pine. This relationship is developed first with site index and then with basal area as the measures of site quality.



Relation of gross cubic volume increment to crown competition factor (CCF) for two stands.

A Tree Area Power Function and Related Stand Density Measures for Douglas-fir, by Robert O. Curtis (37)

How do different measures of stand density compare? PNW Principal Mensurationist Bob Curtis compared numerical values of alternative measures of stand density for three sets of Douglas-fir data. He found that a simple sum of diameters to a suitable power, without reference to other stand characteristics, provided the simplest diameter based measure of stand density.



Comparison of stand density measures for data of the Wind River plantation spacing test, age 42.

Stand Density Measures: An Interpretation, by Robert O. Curtis (38)

Most common measures of stand density are closely equivalent. In general, stand density measures are considered as expressions of the average area available to the trees of a stand. Differences in stand density measures usually occur through the introduction of factors such as stand diameter, height, and volume.

Height Growth and Site Index for Douglas-fir in High Elevation Forests of the Oregon-Washington Cascades, by Robert O. Curtis, Francis R. Herman, and Donald J. DeMars (39)

Height and site index curves for Douglas-fir at high elevations differ from the patterns shown by this same species at lower elevations in the Oregon-Washington Cascades.

According to this report, site index estimation procedures and growth information derived from lowland Douglas-fir are not applicable to high-elevation forests.

This report presents a series of new curves which are applicable to Douglas-fir at high elevations.

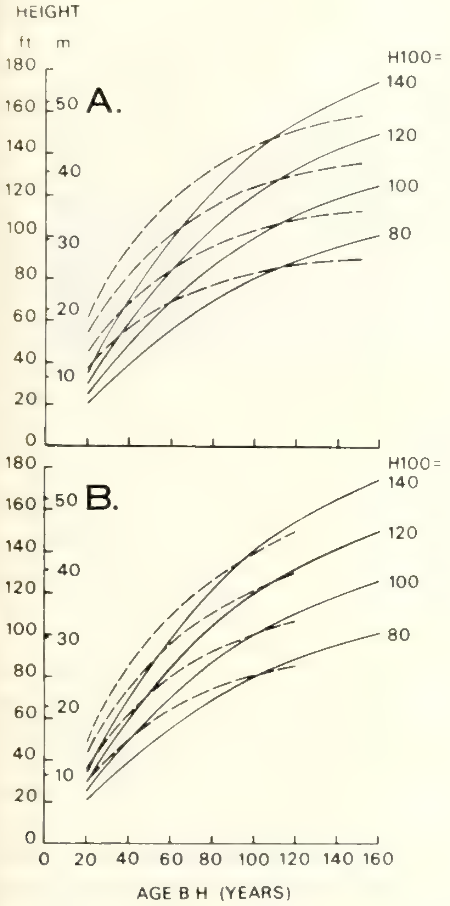
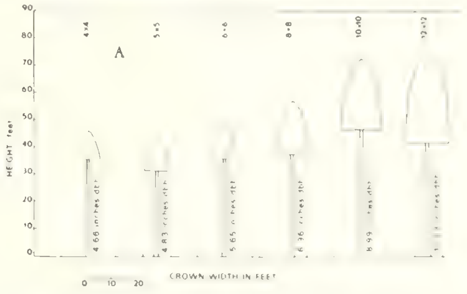


FIGURE 6. *Comparison of shape of new height growth curves for Douglas-fir in high-elevation forests (solid lines) with that of earlier curves for lowland Douglas-fir stands (dashed lines): A, Comparison with curves of McArdle et al. (1961); B, comparison with King (1966).*

Colin MacLean

Crown Development and Site Estimates in a Douglas-fir Plantation Spacing Test, by Robert O. Curtis and Donald L. Reukema (40)

Relationships between stem and crown dimensions of Douglas-fir were examined 43 years after planting. The study took place on Site IV land where initial spacings were from 4x4 through 12x12 feet. The results of the study indicated that average dbh, height, and crown dimensions of the largest trees of comparable crown classes all increased consistently with an increase in initial spacing. In addition, the researchers found that high initial density in low-site stands can lead to serious underestimates of potential productivity.



Comparisons of height and crown dimensions of average trees (quadratic mean dbh) of specified stand components, by spacings, 1965-67 data. (A) all trees 1.5 inches and larger dbh

Estimating Dunning's Site Index From Plant Indicators, by Colin D. MacLean and Charles L. Bolsinger (41)

It is difficult to measure site index on sites where selective cutting has previously removed all or most trees. For areas such as these in California an alternative method of arriving at site index has been proposed using the occurrence of indicator plants and physical variables.

According to the authors, the system uses four simple equations and requires the ability to identify about a dozen shrubs, herbs, and grasses.

Which Dependent Variable in Site Index-Height-Age Regressions? by Robert O. Curtis, Donald J. DeMars, and Francis R. Herman (42)

Here is a paper which discusses the basic concepts and objectives of site index curves. A survey of the literature indicates that two possible systems of curves exist. The first is based on height growth curves corresponding to the regression of height on age and site index. The second system relates site index estimation curves to the regression of site index on height and age. However, the authors point out that these are not the only possible site index concepts and that the optimum method of curve construction depends on the concept adopted and the intended application.

At present, there is a developing timber industry in the interior. Several mills are now in operation, producing lumber for home use and cants for export to overseas markets. This infant industry may be the harbinger of things to come.

It is difficult to separate silviculture from fire when discussing interior Alaska. Fire is the single most important factor in maintaining the vegetational mosaic found throughout much of the interior. The occurrence of wildfire and the immense areas burned contribute to both the frequency and geographical distribution of many tree species.

White spruce is presently the most important commercial species, although the hardwoods show a strong potential for future development. John Zasada, of the Institute of Northern Forestry, has found that the soil requirements for white spruce regeneration include a mineral soil seed bed. The amount of regeneration is greater when scarification is used for site preparation. Zasada has found that clearcutting and shelterwood are equally effective in producing regeneration. However, clearcutting allows more light and heat to reach the soil and may produce more rapid initial seedling growth and establishment. Zasada feels that his research has demonstrated that natural regeneration is generally sufficient to reforest logged stands at present levels of use.

Hardwood research is in its initial stages in interior Alaska. Research plots have been established to investigate the regeneration of birch, poplar, and aspen. Zasada feels that the life cycle of these species in the interior will be similar to that found throughout the rest of their Northern Hemisphere range. Research concerning the hardwoods will become increasingly important as these species enter the developing commercial markets for interior timber.

Alaska is entering a period of growth and expansion. The anticipated division of lands between native corporations and local, state, and federal jurisdictions points to the need for expanded research programs. The research already underway is just a small part of that necessary to insure the wise use of Alaska's forest and related resources.

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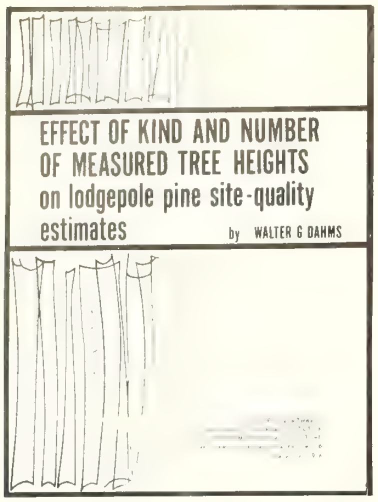
next "insight" page 41



EFFECT OF KIND AND NUMBER OF MEASURED TREE HEIGHTS on lodgepole pine site-quality estimates by WALTER G DAHMS

Effect of Kind and Number of Measured Tree Heights on Lodgepole Pine Site-Quality Estimates, by Walter G. Dahms (43)

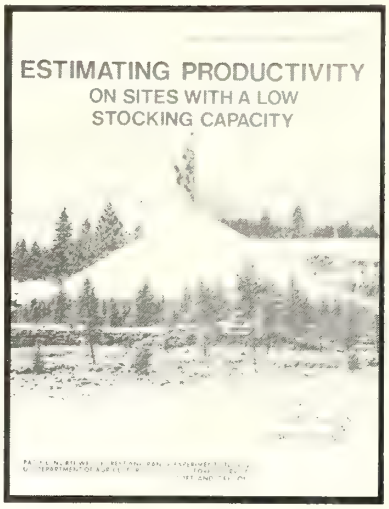
Site index based on tree height and age has become the most widely used method of estimating forest site quality. This paper discusses the relationship between kind and number of tree heights used and the reliability of the resulting site-quality estimates for lodgepole pine.

Productivity Indices for Lodgepole Pine on Pumice Soils, by C.T. Youngberg and W.G. Dahms (44)

In central Oregon, an area characterized by immature or weakly developed soils, productivity for lodgepole pine could not be delineated by soil series alone. Researchers have found that stratifying stands on the basis of understory plant communities provides a better indication of productivity than does stratification on the basis of soil characteristics.

Correction for a Possible Bias in Developing Site Index Curves from Sectioned Tree Data, by Walter G. Dahms (45)

The most serious objection to constructing site index curves with stem analysis methods is that height growth of individual trees does not necessarily represent height growth of stands. Individual trees usually do not retain the same relative height in a stand throughout life. In this paper, researcher Walter Dahms has developed a method of stem analysis for deriving stand height growth from individual tree height growth that is free from the error caused by changes in relative height of trees.



ESTIMATING PRODUCTIVITY ON SITES WITH A LOW STOCKING CAPACITY

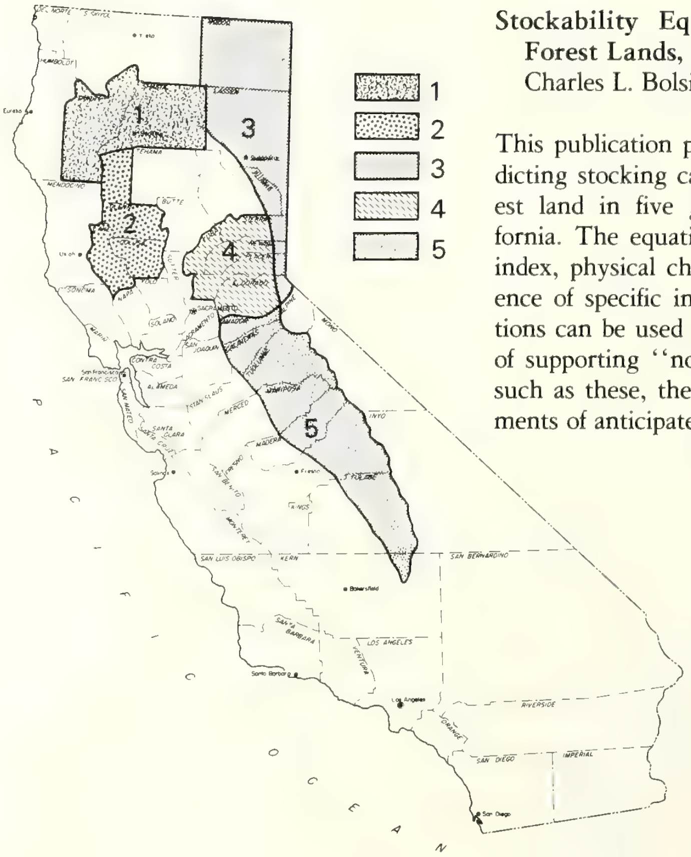
Estimating Productivity On Sites With A Low Stocking Capacity, by Colin D. MacLean and Charles L. Bolsinger (46)

In most areas, normal yield tables are the only tools available for estimating timber productivity and establishing stocking standards. However, the stocking capacity of naturally sparse stands in the arid West is often lower than was found in stands sampled by the makers of normal yield tables. Normal yield table estimates, therefore, may indicate high productivity and understocking for stands that are really well stocked but not very productive.

Several methods are available for estimating productivity on sites of this nature. The first method is to develop factors to discount the normal yield tables in habitat types where a stocking limitation exists. The second method, for areas where habitat types have not been classified, is to predict stocking capacity from multiple regression equations based on site index, elevation, and the presence of indicator plants.

Ponderosa pine on the Colville Indian Reservation growing near the lower limits of occurrence. Stands such as this are naturally sparse.

Jeffrey pine growing on serpentine (peridotite soil) north of Grants Pass, Oregon.



The five geographic areas in California sampled for this study.

Stockability Equations for California Forest Lands, by Colin D. MacLean and Charles L. Bolsinger (47)

This publication presents equations for predicting stocking capacity of commercial forest land in five geographic areas in California. The equations are derived from site index, physical characteristics and the presence of specific indicator plants. The equations can be used to identify areas incapable of supporting "normal" stocking. In areas such as these, the equations provide adjustments of anticipated timber yields.

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resource evaluation

See also:
Mensuration
Alaska

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Forest Survey

The forest survey is one of the oldest research projects in the Forest Service, having been authorized by the McSweeney-McNary Act of 1928. In fact, the forest survey began in 1930 in the Douglas-fir region west of the Cascade Range in Oregon and Washington.

Every year since then, field crews have taken to the woods during the summer to sample and measure the trees. Today, the responsibility of the forest survey has been expanded to include the assessment of other forest resources as well as timber. Under the Forest and Rangeland Renewable Resources Planning Act of 1974, the Secretary of Agriculture is directed to collect, analyze, and report information about all the renewable resources.

The PNW Experiment Station has responsibility for resources evaluation in five states: Washington, Oregon, California, Alaska, and Hawaii. Forest survey information for Alaska will be found in that section. Survey data for Hawaii is published through the Pacific Southwest Forest and Range Experiment Station. Write the Director, PSW Station, P.O. Box 245, Berkeley, California 94701.

Survey data are currently being published by survey units rather than by counties. Survey units for the state of Washington have not yet been determined as the inventory design for that area is currently (1977) being developed. Units for which reports will be published include the following:

California

North Coast: Del Norte, Humboldt, Mendocino, and Sonoma Counties

Central Coast: Contra Costa, and Monterey and Santa Cruz Counties

Northern Interior: Lassen, Modoc, Shasta, Siskiyou, and Trinity Counties

Sacramento: Butte, El Dorado, Nevada and Placer, Plumas and Sierra, Tehama, Yuba, and Glenn, Lake, and Sacramento Counties

San Joaquin: Fresno, Madera and Mariposa, Tulare and Kern, Tuolumne, and Amador, Calaveras, and San Joaquin Counties.

Oregon

Northwest Oregon: Clackamas, Clatsop, Columbia, Hood River, Marion, Multnomah, Polk, Tillamook, Washington, and Yamhill Counties

West-Central Oregon: Benton, Lane, Lincoln, and Linn Counties

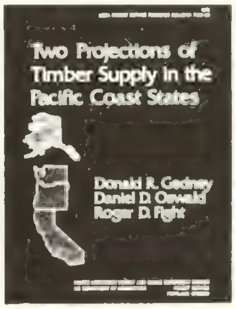
Southwest Oregon: Coos, Curry, Douglas, Jackson, and Josephine Counties

Central Oregon: Crook, Deschutes, Gilliam, Jefferson, Klamath, Lake, Sherman, Wasco, and Wheeler Counties

Blue Mountain: Baker, Grant, Harney, Malheur, Morrow, Umatilla, Union, and Wallowa Counties

Over the years, dozens of reports have been produced by the survey group. As a result, many are outdated or have been superseded by later publications. Only the most current are reviewed here. A list of other major reports that should still be available is found in the bibliography at the end of this section.

timber supply



Two Projections of Timber Supply in the Pacific Coast States

Donald R. Gedney
Daniel D. Oswald
Roger D. Fight

Two Projections of Timber Supply in the Pacific Coast States, by Donald R. Gedney, Daniel D. Oswald, and Roger D. Fight (1)

If the recent level of forest management continues, softwood timber supply will decrease in the Pacific Coast states from the 1970 level of 24.9 billion board feet to 20.8 billion by the year 2000. The projected decrease for fiber is less, from 3.8 billion cubic feet in 1970 to 3.4 billion by 2000.

These trends are not shared equally by each state. In coastal Alaska, a substantial increase is projected. In eastern Oregon and eastern Washington, there is an immediate decrease in supply, then a continuous recovery. In California, western Oregon, and western Washington, the trend is downward.

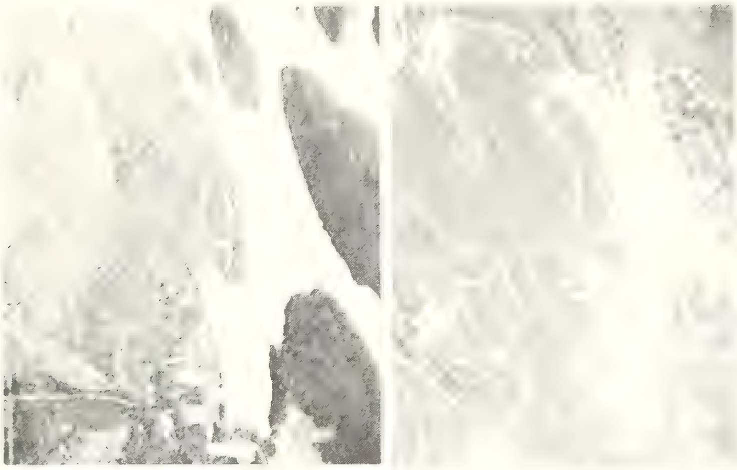
The second projection takes into account the fact that forest management could be intensified to help increase timber yields. More intensive management, with an investment of $469 million on 6.7 million acres would increase total harvest by 201 billion board feet over a six-decade period. However, only nominal increases would be available this century; 86 percent of the increase would occur between 2000 and 2030.

Changes in Commercial Forest Area in Oregon and Washington, 1945-70,
by Charles L. Bolsinger (2)

Between 1945 and 1970, nearly 1 million acres of commercial forest land in Oregon and Washington were taken out of timber production and converted to other uses. Road construction was the leading cause, with urban and industrial expansion second. Other contributing causes were agricultural and powerline clearing, and construction of reservoirs.

An additional 362,000 acres of commercial forest were set aside in reserved areas for parks, wilderness, natural and botanical areas, and other reservations.

Changes in land ownership are also reported. During this time, there was an increase in national forest and forest industry land and a decrease in Indian and farmer-owned land.



Urban expansion is rapidly changing the character of the Puget Sound area in western Washington.

Hardwood Timber Resources of the Douglas-fir Subregion, by Melvin E. Metcalf (3)

Three species dominate the commercial hardwood scene in the Douglas-fir region. Red alder is the most important commercially and makes up nearly 58 percent of the board foot volume of all commercial hardwoods. Bigleaf maple and black cottonwood are next in importance. Other hardwoods that are used commercially include Pacific madrone, tanoak, and white oak.

Statistics are given for acreage by timber type, volume of growing stock, sawtimber, and landowner class.

The Land Base for Management of Young-growth Forests in the Douglas-fir Region, by Roger D. Fight and Donald R. Gedney (4)

The quality and quantity of young-growth stands that exist today will in large part determine future timber supply. This paper reports on the age, stocking, and site productivity of the existing forests in the Douglas-fir region. The data are essential for identifying treatment opportunities such as commercial and precommercial thinning, fertilization, and stand conversion. When combined with response data, assumed management regimes, and harvesting strategies, the data can also be used to project future forest inventories.

California's Forest Industries—Prospects for the Future, by Daniel D. Oswald (5)

California's timberlands and forest products industries have played an important part in the growth of the state's economy. Growth of early communities was dependent on the success of the mills and the demand for lumber.

Forest products industries are still a major factor in many local and some regional economies within the state. But a continually growing and diversified economy has meant less total dependence on timber resources. California's economy will continue to grow and with that growth will come increasing demand for wood products. But self-sufficiency in wood resources is no longer possible. The large areas of old-growth timber have declined and a further decline in log production—to 80 percent levels—is anticipated by the year 2000. Wood products from out of state will become increasingly important in meeting the anticipated growth in demand.

The history of the use of forest resource in California is discussed, trends are given in the forest products industry, and timber supply and employment are projected to the year 2020.

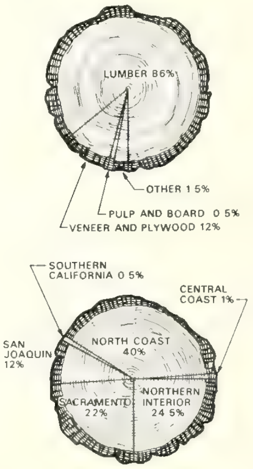
California Forest Industry Wood Consumption and Characteristics, 1972,
by James O. Howard (6)

California is a major producer of many wood products. In 1972, California produced 5.6 billion board feet of lumber, 15 percent of the Nation's total. About 18 percent of the Nation's softwood lumber comes from California.

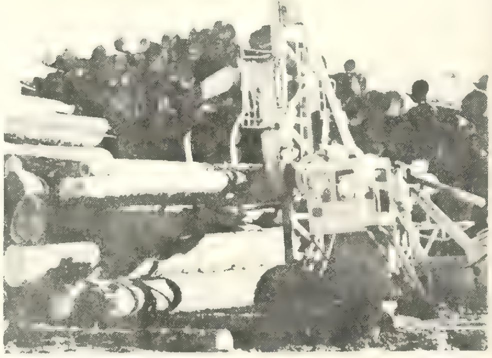
Dramatic changes have taken place in the forest industry in the post-World War II period. Prior to that time, the industry consisted almost entirely of sawmills, with redwood and pines the principal raw materials.

As a result of the post-war building boom and population growth, the sawmill industry increased rapidly—from 450 to almost 1,000 mills during 1945-48.

After 1947, the plywood industry increased rapidly from 20 million square feet production to a peak of 1,305 million in 1964. Up to 1964, Douglas-fir was the primary raw material for these mills. Other wood products industries—including pulp production and hardboard plants—have grown steadily. Today the trend is toward fewer but larger sawmills, increased production in the board industry, and more complex processing operations. Although the industry is still dominated by the sawmill sector, diversification is much greater than before World War II.



Distribution of roundwood consumption by industry and area, 1972.



Oregon Forest Industries, 1972, Wood Consumption and Mill Characteristics, by John P. Schuldt and James O. Howard (7)

This report presents the results of a survey of the primary wood processing industry in Oregon for 1972, and depicts mill characteristics, raw material inputs and residue production and disposition. Data in the survey are broken down for lumber plywood and veneer, pulp and board, shake and shingle, pole and piling, and export industries. This survey provides information on wood flows to industry from various sources, species, harvest areas, the volume of residue utilized, and the raw material requirements of the forest products industries in Oregon.

Reports on the Oregon forest industry are published every 4 years. In 1968, a similar survey was produced by the State Department of Forestry and the Pacific Northwest Forest and Range Experiment Station.

Oregon and Washington Timber Harvest Reports, by J D. Lloyd, Jr.

The volume of timber harvested in Oregon and Washington is reviewed each year in a special 1-page bulletin from the Experiment Station. Order by year and state. For example, the latest reports are:

1974 Oregon Timber Harvest, Resource Bulletin PNW-63 (Revised), by J.D. Lloyd, Jr. (8) and

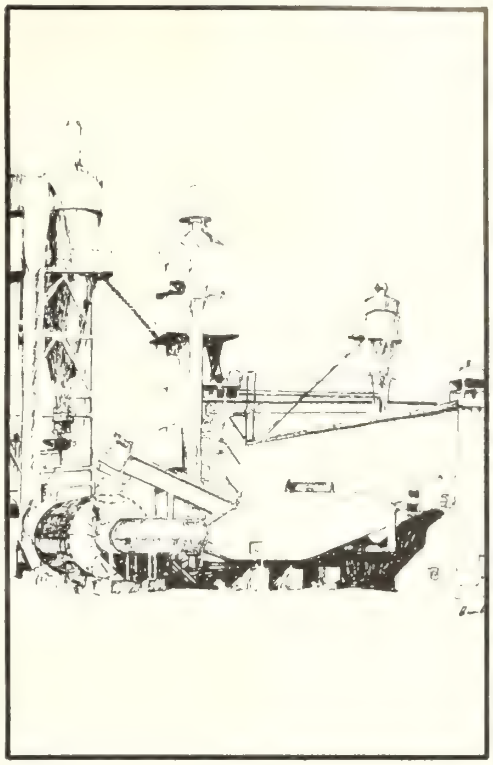
1973 Washington Timber Harvest, Resource Bulletin PNW-61, by J.D. Lloyd, Jr. (9)

Harvest data is given in board feet and compared to the previous year's figures. Statistics are also given for eastern and western portions of the states and by county for various ownerships: private, state, and federal.

Statistics are given for characteristics of the industry, log consumption, and disposition of mill residues. A descriptive analysis of current conditions and past trends is given. Reports on the California forest industry are published every 4 years.

Washington Forest Industry

Information about the forest industry in Washington state is available through the Department of Natural Resources in Olympia. Forest Service researchers have often been cooperators and co-authors of these reports, which are done every 2 years, but they have been published by the state.



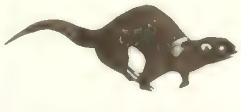
forest survey reports

oregon

Timber Resource Statistics for Oregon, January 1, 1973, by Patricia M. Bassett and Grover A. Choate (10)

For an area as large as Oregon, a complete field inventory of the timber resources is not possible within a single year. Nor is it feasible to reinventory every year to maintain current statistics. But it is possible to make fairly accurate projections of the current timber situation using older data, and updating with computer models.

For this report, timber resource data from forest surveys since 1962 were updated to 1973 using a stand projection model, TRAS (Timber Resource Analysis System), used nationwide by the Forest Survey. Information is given for the national forests and Bureau of Land Management as well as three other ownership classes: other public, forest industry, and farmer and miscellaneous private.



GOLD LAKE BOG— AN OUTDOOR LABORATORY

by Thomas Michael Baugh

Gold Lake Bog is a strikingly beautiful place. It lies in a natural basin at the 5,000-foot elevation of the central Cascades in Oregon. Springs from the surrounding slopes drain into the basin creating moist conditions suitable for the perpetuation of a subalpine bog. Spruce, Douglas-fir, hemlock, and several species of pine and true fir surround the grassy meadows. Marsh plants grow in profusion along the banks of the bog and nearby Salt and Skyline Creeks.

Tons of volcanic ash and pumice were deposited in the basin over 6,000 years ago when Mt. Mazama erupted. Throughout the centuries, this ash has been converted into the soil which today nourishes the bog.

Beaver have dammed the streams and cut channels in the meadow grass. Bobcat, marten, fisher, fox, and other predators stalk their prey in the marshy bottoms. Flying squirrels leap from the surrounding trees while small mammals scurry in the brush and grasses below.

The climate of Gold Lake Bog is normally cool and wet. Summer temperatures are mild with highs in the mid-seventies occurring in July. In winter deep snows cover the land. The tracks of small animals wander along the streambanks in testimony to their passage through the hours of winter darkness. During the spring months the striking pink flowers of bog laurel splash the surrounding slopes with color.

Dr. James Kezer, professor of biology at the University of Oregon, was one of the first scientists to take note of the bog. He discovered the site while hiking in the area about 15 years ago and was impressed by the beauty of the location and the fascinating plants and animals. During that initial visit, Dr. Kezer recorded the presence of several specise of carnivorous plants and noted both the western spotted frog and the Cascade frog.

The interest of Dr. Kezer and others led to a movement to establish a special protectorate for the area. Mrs. Ruth Onthank, a citizen active in environmental causes, led the effort to preserve and protect the bog. She was supported by the Regional Forester for Region 6 of the Forest Service, and the Director of the Pacific Northwest Forest and Range Experiment Station. The effort was successful and in 1965 the Chief of the Forest Service formally established Gold Lake Bog as a Research Natural Area.

The Timber Resources of the Blue Mountain Area, Oregon, by Charles L. Bolsinger and John M. Berger (11)

This report summarizes the findings of the third inventory of the forest in Baker, Grant, Harney, Malheur, Morrow, Umatilla, Union, and Wallowa Counties in eastern Oregon. Fieldwork on lands outside the national forests was completed during the summer of 1969. The Wallowa-Whitman National Forest was inventoried in 1966 and 1967, the Malheur National Forest in 1967 and 1968, and the Umatilla National Forest in 1968 and 1969. Inventory of the Snow Mountain Ranger District of the Ochoco National Forest in Grant and Harney Counties was completed in 1967, and that of the Crooked River Working Circle in Grant County was completed in 1962.

The inventory indicates that there are about 47 billion board feet of sawtimber on 4.6 million acres of commercial forest land in the Blue Mountain area. Public agencies administer about 76 percent of the area and hold 89 percent of the sawtimber volume; farmer and miscellaneous private ownerships account for 16 percent of the area but only 6 percent of the sawtimber volume; and forest industries 8 percent of the commercial forest area and 5 percent of the volume. Total volume of timber and area of commercial forest land has declined about 10 percent since the mid-1950's.

Ponderosa pine is the most abundant species, accounting for 44 percent of the sawtimber volume. Douglas-fir accounts for 20 percent of the volume, with true firs and larch occurring in significant amounts.

Most of the available timber volume is in public ownership. Private timberland is largely cut over, with resulting low inventory volumes. Although total timber cut has remained at about the same level, the harvest from public lands has increased from 56 percent in 1960 to 82 percent in 1972.

Chuck Bolsinger

Timber Resource Statistics for Central Oregon, by John M. Berger (12)

Results of the third inventory of timber resources are summarized for the nine counties in central Oregon: Crook, Deschutes, Gilliam, Jefferson, Klamath, Lake, Sherman, Wasco, and Wheeler.

Field data for central Oregon were collected for all lands except the national forests during the summer of 1964. Data for the national forests were collected between 1957 and 1962.

Commercial forest land in the region totals 6,255,000 acres and makes up 35 percent of the land area. Growing stock volume totals 13,849 million cubic feet, with 82 percent of that in four species: ponderosa pine, lodgepole pine, white fir, and Douglas-fir.

Statistics are also given on sawtimber volume, by various forest ownerships, and for net annual growth, mortality, and average annual cut for the 5 previous years.

Timber Resources of Douglas County, Oregon, by C.D. MacLean (13)

Douglas County has 66 billion board feet of sawtimber—75 percent federally owned and 21 percent owned by the forest industry. Sixty percent of the private commercial forest land has been clearcut and an additional 20 percent partially cut. At the current rate of harvest, the private sawtimber inventory will not last 20 years.

Poor conifer stocking prevails on more than half the county's clearcut area. About one-third of the federal clearcut area, over half of the forest industry clearcuts, and over two-thirds of the other private clearcut lands are inadequately stocked with conifers. Many of the poorly stocked acres are on "tough sites" where planting is both expensive and uncertain of success.

About half the commercial forest area in the county is suitable for final or intermediate harvest. Another 20 percent is either nonstocked or partially stocked with conifers and needs planting or stand conversion. Many of the poorly stocked acres are now covered with brush or hardwoods. Four percent of the commercial forest land—all in nonindustrial private ownership—is brushy, nonstocked cutover on low site where treatment is not feasible because of high cost, low return, and the likelihood of failure.

Immature stands of conifer stock 22 percent of the county's commercial forest land. However, over half these stands would grow faster if excess competition were removed, either through cleaning of brush and hardwoods or through precommercial thinning.

washington

Timber Resource Statistics for Washington, January 1, 1973, by Patricia M. Bassett and Grover A. Choate (14)

For an area as large as Washington, a complete field inventory of the timber resources is not possible within a single year. Nor is it feasible to reinventory every year to maintain current statistics. But it is possible to make fairly accurate projections of the current timber situation using older data, and updating with computer models.

For this report, timber inventory data was updated to January 1, 1973, using a stand projection model, TRAS or Timber Resource Analysis System, a method used nationwide by the Forest Survey. In general, most information used in this report was updated from the 1970 estimates for *The Outlook for Timber in the United States* published by the Forest Service in 1973(15).

The Timber Resources of the Inland Empire Area, Washington, by Hal A. Arbogast (16)

Statistics are given from the latest inventory of the timber resources of the 12 easternmost counties in the Inland Empire area of Washington.

The inventory indicates that there are 24 billion board feet of sawtimber on 3.9 million acres of commercial forest land. Public agencies administer about 56 percent of the area and 70 percent of the sawtimber volume, farmer and miscellaneous private ownerships account for 37 percent of the area but only 22 percent of the sawtimber volume, and industry 8 percent of the total commercial forest area and 8 percent of the volume.

Douglas-fir is the most abundant species, accounting for 30 percent of the sawtimber volume. Ponderosa pine accounts for 29 percent of the volume, with larch and true firs also occurring in significant amounts.

The forests of the Inland Empire are young, although the 12 percent of old growth is the principal source of timber for the area's forest industries. For the area as a whole, growth exceeds cut, with most of the growth on lands in farmer and miscellaneous private ownership. This imbalance could result in increased timber harvesting, depending on industry's willingness to process smaller timber from these types of owners and the individual owner's management objectives.

Forest Industries of Eastern Washington, by Brian R. Wall, Donald R. Gedney, and Robert B. Forster (17)

A sawmill, built in 1872, marked the beginning of the forest industry in eastern Washington—almost half a century after the emergence of the lumber industry in western Washington. Since then, this industry has increased in importance to eastern Washington's economy, now furnishing about one-fifth of the total manufacturing employment and wages paid—in some counties and many communities, it is the major source of employment and wages. In 1962, various forest products firms paid about $43 million in wages to more than 8,000 employees.

The forest industries are not only important to the whole economy of eastern Washington, but the health of these industries determines how intensively the forest resource can and will be managed. In order to inform those interested in the forest resource as well as those interested in the general economy of eastern Washington, the primary forest industries are examined in this paper; these include lumber, pulp, plywood, and a number of relatively smaller forest industries. The basis for this examination is a survey, made during the summers of 1963 and 1964. Each wood manufacturing plant was personally contacted, and information was obtained on log consumption, source of logs, equipment, production, degree of manufacturing, and use of mill residues.

The single most important forest industry in eastern Washington is lumber. To obtain additional background, a study was made of the numbers and stability of sawmills between 1945 and 1963.

Timber Resources and the Timber Economy of Okanogan County, Washington, by Charles L. Bolsinger (18)

In 1972, forest industries in Okanogan County, Washington, accounted for 23 percent of total employment and 29 percent of wages paid. Total forest industrial employment has increased since 1953 but represents a smaller proportion of total employment in the county due to the increase in other industries, mainly construction and trade. Timber harvest has nearly doubled since 1953, from 116 million board feet to 198 million. In 1972, 90 percent of the timber harvest was from public lands compared with 76 percent in 1953.

Timber supplies are projected to decline slightly—about 4 percent—by the year 2020, though the value is expected to increase about threefold. Employment in forest industries is projected to decline about 60 percent by the year 2020, but forest industrial payrolls will decline by only 27 percent.

The Timber Resources of Central Washington, by James O. Howard (19)

The findings of the latest inventory of the timber resources of central Washington indicate there are 50.9 billion board feet of sawtimber on 4,370,000 acres of commercial forest land. Land owned or administered by public agencies accounts for 73 percent of the area and 84 percent of the sawtimber volume; farmer and miscellaneous private ownerships account for 17 percent of the area but only 9 percent of the volume; and the forest industry sector is smallest, with only 10 percent of the area and 7 percent of the volume.

About 280,000 acres are classified as nonstocked. Much of this occurs in the lower fringe of the forest zone and may not be able to support additional stocking.

Douglas-fir is the most abundant species, occurring on 37 percent of the commercial forest land and accounting for 38 percent of the sawtimber volume. Ponderosa pine is found on 27 percent of the area and accounts for 24 percent of the volume. True firs cover only 10 percent of the area but account for 17 percent of the volume.

Poletimber stands cover 809,000 acres, with about 220,000 acres classified as overstocked. These stands present a problem of reduced future yield unless they are thinned. Harvest exceeds growth by almost 200 million board feet, primarily because of a large volume of old-growth timber and the low overall site productivity of the area.

Recreational use of the forests of central Washington has been increasing rapidly. Associated with this increased demand has been pressure to reserve land area exclusively for recreation use. Presently there are almost 800,000 acres in reserved status.

Forest Lands of Central Washington

Natural areas, such as Gold Lake Bog, are tracts of land basically undisturbed by the activities of man. For this reason they can provide comparisons with similar types of land which have been heavily used. Scientists can study both the animal and plant life in these outdoor laboratories with reasonable assurance that the complex ecosystems will remain much as nature evolved them.

Five species of carnivorous plants grow in the sphagnum moss of the bog. Two species of sundew and three species of bladderwort share the area with other, more common plants. Although deadly to some forms of small insect life, the carnivorous plants are fascinating to students of nature. This grouping of remarkable plants makes Gold Lake Bog one of the biological treasures of the Cascades.

Scientists feel that the adaptations which allow the plants to feed on insects may have some relation to a lack of soil nutrients. The plants are usually found on damp, acidic soils which are deficient in nitrogen. The root systems are often poorly developed and it is possible that the plants obtain nitrogen from the bodies of the trapped insects.

Each plant has developed its own bizarre adaptations. The red, jewel-like tentacles on the leaves of the sundew plant are tipped with a clear, sticky substance which traps insects. As the insect struggles against this natural glue, the leaves begin to slowly fold. More and more tentacles come in contact with the prey until it is pinned down and enclosed by the leaf. Glands within the plant secrete a digestive enzyme which consumes parts of the insect. When the process is completed, the sundew leaf unfolds exposing the undigested remains. Both the round leaved (Drosera rotundifolia) *and long-leaved sundew* (Drosera longifolia) *thrive at Gold Lake Bog.*

The bladderwort is less spectacular in appearance than the sundews but has a much more intricate device for capturing small aquatic animals. This rootless plant grows in the wet sphagnum moss of the ponds of the bog. The stalks of the bladderwort support tiny, pear-shaped bladders. The flattened end of each bladder conceals a trapdoor surrounded by hair-like filaments. The filaments guide small animals such as the Daphnia *down to the surface of the trap where they trigger small "pegs" which spring the trap. The trapdoor opens and the inrushing water pulls the prey into the bladder where it is digested.* Utricularia minor, *a relatively rare bladderwort, is included among the three species found in the still waters of the bog.*

Timber Resources of the Puget Sound Area, Washington, by Charles L. Bolsinger (20)

The latest inventory of the forest resources in the Puget Sound area shows a total of 3,300,000 acres of commercial forest land and 74,859 million board feet of sawtimber volume. Since 1953, about 221,000 acres of commercial forest land have been converted to roads, powerlines, reservoirs, agri culture, and urban and industrial developments, and about 65,000 acres have been set aside in parks and other reserved areas. Total sawtimber volume has decreased about 8 percent; softwoods have decreased 11 percent, while hardwoods have increased 71 percent.

About 41 percent of the commercial forest land is in public ownership; 59 percent is private, with forest industries holding 28 percent and farmers and miscellaneous private owners, 31 percent. About 20 percent of the commercial forest land is in old-growth timber, and over half of this is in national forest ownership. Other public owners have 13 percent of the old growth; forest industries, 28 percent; and farmers and miscellaneous private owners, 8 percent.

Douglas-fir is the most extensive forest type but is estimated to cover only half as much area as it covered in the 1800's before settlement of the Puget Sound area. Over 600,000 acres of logged and burned country now stocked with hardwoods, and many agricultural areas, roads, reservoirs, and town and industrial sites were once Douglas-fir forest.

Though Douglas-fir is the most extensive forest type, there is more western hemlock volume—24 billion board feet of hemlock compared with 21 billion Douglas-fir. This is because much more of the Douglas-fir type is young growth with less volume per acre.

Aerial seeding of Douglas-fir

Western redcedar stands such as this, typical of the coastal cedar belt, cannot be grown on a continuous yield basis.

The Timber Resources of the Olympic Peninsula, Washington, by C.L. Bolsinger (21)

This report summarizes the findings of the fourth inventory of the forests in Clallam, Jefferson, Grays Harbor, Mason, and Thurston Counties in Washington. Fieldwork on lands outside the national forests was completed during the summer of 1965. Fieldwork for the Olympic National Forest was completed in 1963, and for the Snoqualmie National Forest, a small portion of which lies in southeast Thurston County, in 1965.

The fourth inventory shows a total of 3,105,000 acres of commercial forest land and 81,464 million board feet (International 1/4-inch scale) of sawtimber volume. Total timber volume has remained about the same for the past 12 years, and cut and growth currently are nearly in balance.

Compared with the Douglas-fir region as a whole, less of the forest in the Olympic Peninsula is in a poorly-stocked condition, and a greater proportion is in fast-growing young conifer timber. The generally good condition of the forest reflects the high growth potential of the forest land and the relative ease with which lands restock. Most of the present young sawtimber stands originated after logging or burning in the timber boom period of the late 1800's and early 1900's, or as a result of the February 1921 windstorm. Although most of these young-growth stands originated by chance, forest protection the past few decades has been important in their survival and development.

california

Timber Resources of Mendocino and Sonoma Counties, California, by Daniel D. Oswald (22)

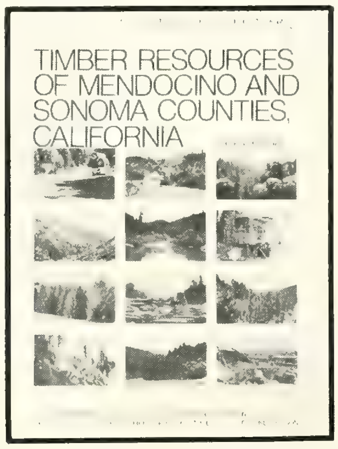
Information from the first complete inventory of timber resources in Mendocino and Sonoma Counties is presented. Data were collected during several field seasons in 1964, 1965, and 1967.

Findings indicate there is 19.1 billion board feet of sawtimber on 1,564,000 acres of unreserved commercial forest land in these two counties. Forest industries own about 34 percent of the commerical forest area and 37 percent of the timber volume; farm and miscellaneous private ownerships account for 53 percent of the area but only 42 percent of the volume; and public ownerships account for 13 percent of the area and 21 percent of the volume.

Almost half the commercial forest area is stocked with low value hardwoods and scattered conifers. This condition has resulted from wild fires, logging, and unsuccessful or abandoned attempts to convert timberland to grazing land. Redwood is the area's most abundant conifer, predominating on 368,000 acres; sawtimber volume in this species is 9.6 billion board feet. Douglas-fir type is found on 281,000 acres; sawtimber volume is 6.5 billion board feet.

The forests in these counties are predominantly young, 79 percent of the area having stands under 100 years old. These young forests are responsible for almost all of Mendocino-Sonoma's 499 million board feet of net annual growth.

In recent years, the forest industries of these counties have been utilizing old-growth timber, more Douglas-fir than redwood, and have been relying heavily on their own holdings. In the next 10 to 15 years, the realities of raw material availability will likely lead industry to greater reliance on young redwood sawtimber, much of it from farm and miscellaneous private lands.



TIMBER RESOURCES
OF MENDOCINO AND
SONOMA COUNTIES,
CALIFORNIA

Timber Resources of Northern Interior California, 1970, by C.L. Bolsinger (23)

This report summarizes a timber resource inventory in Lassen, Modoc, Siskiyou, Shasta, and Trinity Counties, California. Included are detailed tables of forest area, timber volume, growth, mortality, removals, and a discussion of the current timber resource and timber industry situation.

The five-county area contains 9.6 million acres of forest land, of which 6.0 million acres are classified as commercial, 3.2 million as unproductive, and 0.4 million as productive reserved in parks and other reservations. About 60 percent of the commercial forest land is in public ownership; 40 percent is in private ownership.

The total standing timber volume is estimated at 86.0 billion board feet—more softwood sawtimber than occurs in the states of Georgia, North Carolina, and South Carolina combined. Since 1953, total timber volume has declined 17 percent on public lands and 45 percent on private lands. The decline was primarily because of logging, but several large fires and forest conversions have also contributed.

Net annual growth on all ownerships is about 1.25 billion board feet, and annual mortality is about 0.2 billion board feet. National forests have the highest per-acre growth rate and the lowest mortality relative to inventory volume. Private lands have lower growth and higher mortality because of the relatively poor condition of many cutover stands. About 75 percent of the land in these ownerships has been cut over. Growth has increased on private lands, and there is reason to expect better performance in the future.

The annual timber harvest has remained stable for the past 20 years at 1.3 to 1.5 billion board feet. The cut gradually shifted from the eastern to the western part of the five-county area and from private lands to national forests. Private lands will continue to provide the smaller proportion of the timber harvest in the foreseeable future. The species harvest has shifted from pines to Douglas-fir and later to white and red firs. In the near future, the pine harvest will continue to decline as Douglas-fir and the white and red firs account for a greater portion of the total cut.

The Timber Resources of Humboldt County, California, by Daniel D. Oswald (24)

This report presents the first complete inventory of Humboldt County's timber resources. Field data were collected during the summer of 1966 and are presented as of January 1, 1967.

Humboldt County has been an important source of raw material for wood products for over 100 years. This county, which has the largest sawtimber inventory and second largest commercial forest area of all California counties, is largely responsible for California's position as a leading state in production of wood products. Since 1920, Humboldt County's forests have yielded over 33 billion board feet of roundwood for manufacture of wood products, 20 billion board feet of it in the last 15 years. In 37 of the last 47 years, Humboldt County has led all other California counties in roundwood harvest and lumber production and has never ranked lower than third during the remaining 10 years.

Humboldt County today leads the state in the production of lumber, softwood veneer and plywood, and woodpulp. It accounts for one-quarter of the state's annual timber harvest, and its sawmills provide more residue for pulping than any other county.

Softwood Tree Volume Equations for Major California Species, by C.D. MacLean and J.M. Berger (25)

New cubic-foot, International 1/4-inch board foot, and Scribner board-foot tree volume equations have been developed for eight species: Douglas-fir, ponderosa pine, Jeffery pine, sugar pine, lodgepole pine, white fir, California red fir, and incense-cedar. Although developed specifically for use in the forest survey of California, they are suitable for general use throughout the state, wherever total height, d.b.h., and volume equations are needed.

The equations were developed from measurement data from 2,110 felled trees and 957 dendrometer-measured trees from sites extending from the Modoc plateau to the southern Sierra Nevada. Data from the Coast Ranges were unavailable. Both equations and volume tables are presented.

Other Publications

For other publications on this same subject, see listing in bibliography under (26).

Dan Oswald

Two species of frogs are found within the varied wildlife population of Gold Lake Bog. The Cascade frog (Rana cascadae) *can generally be found inhabiting the fringes of the bog, while the western spotted frog* (Rana pretiosa) *prefers the interior. Scientists who have worked in the area have discovered that these two amphibians are genetically compatible and interbreed. Colorful frogs showing the characteristics of both species have been collected.*

There has been very little man-caused disturbance at Gold Lake Bog. In the past, wildlife managers removed beaver dams which were blocking the upstream migration of rainbow trout into nearby Gold Lake. During the fall months, hunters used to camp in the higher, drier portions of the basin. Both of these activities have stopped since Research Natural Area designation and the visits of man are now limited to those who are interested in the bog for scientific and educational purposes.

Gold Lake Bog is just one of over 500 Research Natural Areas located throughout the United States. Human impacts are carefully controlled by the federal agencies responsible for the protection of the areas. Formal permission for visitation is the rule. Scientists are generally limited to nondestructive studies although infrequently small amounts of collected material are removed with prior permission. No activities are allowed which will alter the basic nature of these outdoor laboratories.

Commercial and recreational use of the wildlands continues to grow, chipping away at those places which remain essentially pristine. Scientists Jerry Franklin and James Trappe of the Pacific Northwest Forest and Range Experiment Station recognized this problem when they wrote, "Even the West, long considered a reservoir of lands unaffected by man, will not be so in the forseeable future." These researchers point out that the "opportunities for establishing adequate, representative natural area systems are quickly vanishing."

The concern expressed by Franklin and Trappe is shared by many others. For this reason, the search for these unique, untouched islands in a rapidly developing landscape continues. It is conceivable that areas such as the Gold Lake Bog may someday provide the only links between man and the undisturbed past of this magnificent continent.

end

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resource evaluation-bibliography

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genetics

See also: Silviculture

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General

Foresters have known for a long time that some trees grow taller, faster, and bushier than others, and that they vary in their resistance to disease and insects, or survive greater extremes of environment. Although site conditions, climate, and adequate sunlight and nutrients are important to tree growth and survival, it is their inherited traits that determine how they will respond to these conditions.

The goal of forest genetics research is to improve tree growth and other desirable traits without losing the adaptiveness that is already present in the gene pool. Basic laboratory studies and practical work in the forest complement each other in the Forest Service research program. Most of the research has been done on Douglas-fir, the most important timber species in the Pacific Northwest.

The Care and Handling of the Forest Gene Pool, by Roy R. Silen with Ivan Doig (1)

The 22 commercial conifer species of northwestern America constitute a unique pool of genes. They outproduce other temperate species in the droughty climate and ordinary soils of the West. This uniqueness probably reflects the fact that the species survived the ice ages intact, with each locality having selected an exactly adapted race. Alteration of the gene pool, randomly with planting and deliberately with genetics, is now a certainty. The current philosophy, like mining, discards all the gene pool except pure, profitable genotypes. A plea is made for a more cautious approach.

tree development, environmental effects

Frequency of Seedlings from Natural Self-Fertilization in Coastal Douglas-fir, by Frank C. Sorensen (2)

In many plant species, including forest trees, the progeny which result from inbreeding are less vigorous and less competitive than those which come from crossing. Trees, having both male and female reproductive structures, can fertilize themselves (self-fertilization or selfing), an extreme form of inbreeding. The natural regeneration strategy of a species such as Douglas-fir often leads to the formation of ''family groups'' around individual trees or portions of stands. Mating between members of the same family group or between a parent tree and one of its offspring also leads to inbreeding, but less extreme than selfing.

In most species seed and plant quality can be upgraded by avoiding inbreeding. While there is not much foresters can do to prevent inbreeding in the forest, operators of seed orchards should try to minimize inbreeding in seed orchard progeny.

In 1964, geneticist Frank Sorensen began studies of self- and cross-pollination in stands of Douglas-fir in western Oregon. Later studies were begun in ponderosa pine and noble fir.

Some of the effects of inbreeding on fertility and vigor which are reported in these related publications (3) are given below:

- Self-fertility in Douglas-fir is low. Most self-fertilizations end up as empty seeds because the weak self-embryos abort before completing their development. On the average, Douglas-fir produces only about 11 percent as many filled seeds after self-pollination as after cross-pollination. For ponderosa pine it is about 35 percent, for noble fir about 70 percent.

- Weight and germination of filled seeds from self-fertilization are only slightly less than for seeds from cross-pollination. However, survival of self-seedlings is about 10 percent less and seedling nursery height about 25 percent less than for seedlings from cross-pollinations.

- Self-fertilization also reveals trees which carry recessive or ''hidden'' genes for mutant traits such as albinism. These mutants are used to study pollen flight and natural inbreeding. In Douglas-fir it has been found that about 7 percent of the seedlings from wind pollination are self-seedlings, and the inbreeding depression in stem volume is about 5 percent compared to the same family with no inbreeding.

- The frequency of self-seedlings in the wind-pollination progeny of several tested Douglas-fir trees ranged from 0 to 27 percent. An undesirably high frequency for a particular tree results from combining a good pollen crop and high inherent self-fertility, with flower receptivity ahead or behind the average of the stand. This is further magnified if the tree is growing in a cluster of relatives which inter-pollinate, or is in a two-story stand and receives pollen from one or both of its parents.

Operators of tree improvement programs may wish to read specialized reports by Sorensen concerning the response of Douglas-fir to environmental changes (4).

Frank Sorensen

Self-Pollination Effects on Seed and Seedling Traits in Noble Fir, by Frank C. Sorensen, Jerry F. Franklin, and Robert Woollard (5)

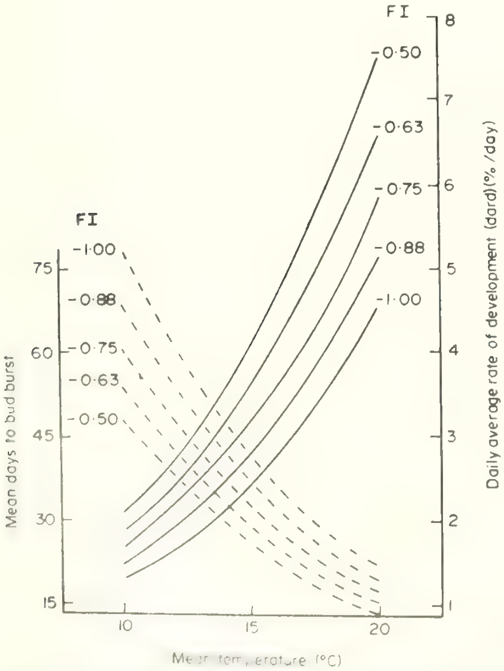
Artificial regeneration in noble fir, an important upper slope conifer in western Oregon and Washington, is complicated by the relatively low germination of seed, a characteristic of the species.

This study tested the idea that poor germination might be the result of self-pollination. Results, however, did not confirm the researchers' suspicions. Some other cause is more likely.

Use of Phenology for Examining Provenance Transfers in Reforestation of Douglas-fir, by Robert Campbell (6)

Foresters learned long ago that local seed is usually best for reforestation purposes, but there are times when local seed is not available. Campbell explores ways to use the timing of bud burst to predict the response of seedlings to geographic transfers. Seed collected at 44 locations in western Washington, Oregon, and northern California was planted and grown at different temperatures in a greenhouse. Buds of seedlings from the 44 locations burst at different times, depending on temperature. This information was used to predict the dates of bud burst for seedlings planted in various locations.

Results indicate that moving seed in east-west directions is more likely to be harmful than moving it north or south an equivalent distance.



Mean days to bud burst and daily average of development towards bud burst as a response to mean daily temperature.

Bob Campbell

Predicting Bud Burst in Douglas-fir

This report covers the same subject as (6) but was written a year later and takes the preceding study further. While the mechanism by which perennial plants adapt to variable seasonal climates is not completely understood, it appears possible to predict some plant behavior, specifically bud flushing in seedling Douglas-firs.

Three growth chamber experiments were used to examine the seedlings' response to combinations of chilling, photoperiod, and temperature during dormant and postdormant phases. On the basis of the results, Campbell proposed a conceptual model for the action of temperature and photoperiod on the time of bud flushing. On the average, bud burst is advanced by 0.4 days per degree C rise in average temperature, but this rate is influenced by length and temperature of chilling. The longer the chilling period that precedes bud development, the greater the rate of bud development at a given temperature. Also, the longer the photoperiod during the flushing period, the greater the rate of bud development. The report is titled, *Phenology of Bud Burst in Douglas-fir Related to Provenance, Photoperiod, Chilling, and Flushing Temperature,* by Robert Campbell and Albert I. Sugano (7).

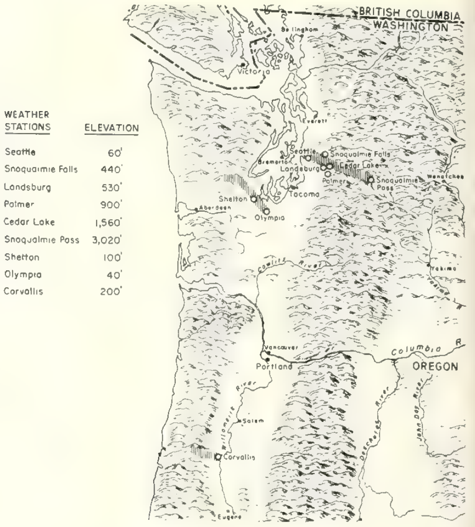
A Study of Genetic Control of Bud Bursting in Douglas-fir, by Roy R. Silen (8)

Silen investigated the degree of genetic control over bud bursting in Douglas-fir by grafting scions from trees with widely different bud bursting dates onto limbs of seven trees of a 17-year-old clone. The experiment included replications of seven scion types on each clone tree, the seventh type being a control graft in which a limb of the clonal tree was cut, then regrafted.

The conclusion was that practically all variation in bud bursting is genetic. Differences in bud burst of the seven scion types were consistent. Results also showed that local environment differences may delay bud bursting of genetically similar material for as much as 2 weeks.

Does Rainy Weather Influence Seed Set of Douglas-fir? by R.R. Silen and K.W. Krueger (9)

Rainy weather during the pollination period has been considered one of the reasons for low yields of seed from Douglas-fir cones. A preliminary study during 1959 indicates that rain during the pollination period could not cause a major reduction in Douglas-fir seed set over a broad elevational zone.



Location of transects and weather stations.

Cold-Acclimation in Seedling Douglas-fir Related to Phenology and Provenance, by Robert K. Campbell and Frank C. Sorensen (10)

One-year-old seedlings from 10 provenances from the Coast Ranges of Washington and Oregon were growing in cold frames at Corvallis, Oregon, when they were damaged by frost in October 1969. The occasion offered an opportunity to study the ability of the seedlings to survive frost damage. Results indicate that the longer the time between bud set and fall frost, the less damage occurred to the seedlings. Since trees from southern sources generally set buds later and are more sensitive to frost than those growing farther north, they were more severely damaged. Those from southern Oregon coastal sources were the most sensitive.

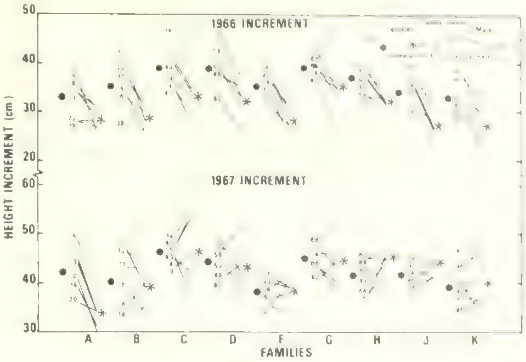
Spacing-Genotype Interaction in Douglas-fir, by Robert K. Campbell and Boyd C. Wilson (11)

One of the potential problems for tree breeders had been the possibility that the space allowed for each seedling in the plantation might affect the performance of the seedlings and thus the selection of the best tree families for breeding. Results of this study showed that spacing did not affect the growth ranking of seedling families enough to present a problem.

Genetic Variability in Juvenile Height Growth of Douglas-fir, by Robert K. Campbell (12)

Seedlings often must compete with brush species in early life and are also vulnerable to browsing by animals. Various methods have been tried to increase early seedling growth to get them through this vulnerable stage. These include planting in containers or machine planting on terraced slopes, followed by fertilizing, irrigating, or mulching.

Campbell studied the possibility that growth of trees from different families might vary greatly depending on plantation location. Trees that are most productive at one location might be least productive at another, thus hindering selection of best families for breeding. Results indicate that location affected the ranking of families enough to present a problem.



Mean 1966 & 1967 height increments for full- and half-sib families grown at two locations

tree improvement

A Simple, Progressive, Tree Improvement Program for Douglas-fir, by Roy R. Silen (13)

In 1966, after serious technical problems arose in Douglas-fir seed orchards, geneticist Roy R. Silen proposed a simple, low cost tree improvement program that obviated need for orchards. Based upon known performance of tree families in a 50-year-old study, ample gains could be shown using wind-pollinated seed collections from individual parent trees once their ranking was known from a wind-pollinated test of their progeny. The program was originally designed for small landowners.

Silen's proposal was that a large enough number of trees be selected and tested to produce three times the seed needed by the owner. As wind-pollinated seedlings in the test grew in size, the landowner improved his ability to select the genetically better third. The proposal had other features, such as use of a very restricted seed zone, major dependence upon testing, use of existing forestry staffs, and provisions for a long term breeding program to follow.

The program caught on. By 1976, 32 owners of 6.1 million acres of forest land in Oregon and Washington, mostly in tree improvement cooperatives, were using the program.

Douglas-fir Seed Orchard Problems—A Progress Report, by Roy R. Silen and Donald L. Copes (14)

Grafted seed orchards are a major part of several Douglas-fir tree improvement programs in the Pacific Northwest.

This publication reviews progress toward solving three problems common in seed orchards: (a) graft incompatibility, (b) contamination of the seed orchard by pollen from outside the orchard, and (c) the excessive length of time it takes Douglas-fir to produce an abundant cone crop after grafting.

Copes was assigned full time to study graft rejection in 1965. He found that a wounding and rehealing phenomenon was associated with incompatibility and could be detected microscopically. He began making two grafts per parent tree on each root stock. After 1 year he cut off one graft from each root stock and examined it in the laboratory. If the rejection process had begun, abnormal cell types would be seen and the graft eliminated. Once a compatible root stock was found, additional rootstocks could easily be produced by rooting cuttings from that rootstock.

Silen developed a method (15) to avoid contamination by outside pollen. Solution to the problem of better cone production was being approached by many laboratories through studies of hormonal, nutritional, and day-length requirements.

Don Copes

ANOTHER WAY TO CRUISE TIMBER

by Louise Parker

Over the years, there's been a lot of discussion about which is the best method of selling timber—by lump-sum or scale. Both methods involve cruising, the measuring and grading of trees to determine the volume and the value of the timber in a sale area. In a lump-sum sale, the timber is cruised, a price tag is put on the whole stand, and the timber is sold "lump sum." In a scale sale, cruising is done and a per thousand-board-foot price is established and applied to the logs that are taken from the woods. Scale sales require special measuring or "scaling" stations.

Both kinds of sales apparently have advantages and disadvantages. For example, scale sales are costly and may encourage operators to leave a lot of residue in the woods, because buyers only pay for what they take out On lump-sum sales, all the merchantable material is paid for, so buyers may be more inclined to take it all. But, lump-sum sales can be inaccurate.

A technique called "fall, buck, and scale (FBS) cruising" offers another option. With it, timber growers can sell lump-sum, without having to measure every tree in the sale area. And, the accuracy of FBS cruising is such that scaling is not required after logging.

There are many other advantages of FBS cruising over older methods. In a traditional cruise, the cruiser uses biltmore sticks, optical measuring devices, and "guestimate" to estimate the volume and value of standing trees. FBS cruising, in contrast, employs a totally new concept. Instead of measuring trees as they stand, sample trees are felled, bucked into standard log lengths, and measured on the ground. The cruiser can measure the diameter and length of the logs as they are cut, and can accurately determine defect, breakage, taper, and other factors which are hard to evaluate on standing trees.

FBS cruising was developed by the Bureau of Land Management in cooperation with researchers at the PNW Station in Portland, Oregon. The original idea for the method can be traced to Leonard Zygar, a cruiser with BLM's Salem District in Oregon. At a training session several years ago, Zygar asked, "Why not cut the sample trees?"

The solution seems so simple that a lot of people wonder why no one thought of it before. One reason is that, until recently,

Cooling a Douglas-fir Seed Orchard to Avoid Pollen Contamination, by Roy R. Silen and Gene Keane (15)

Contamination from outside pollen sources was a major obstacle to developing a successful seed orchard technology for Douglas-fir. Pollen dispersion in the Douglas-fir region is extensive during good years when pollen counts of several thousand per square inch are common.

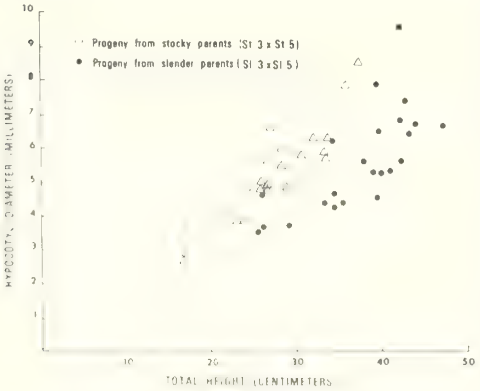
A 1968 study carried out at the Forest Service Heather Seed Orchard near Oakridge, Oregon, showed that floral development could be slowed by irrigating the trees with cold water. Female buds, cooled by a water spray for a month prior to local pollen release, remained in their scales long enough to reduce pollen contamination to a tolerable level. Seed developed normally after 6 weeks of spraying, and pollen produced in the sprayed plots appeared normal in germination tests.

Several commercial trials of irrigation have since been successful and the principle has been widely applied to control phenology of fruit crops.

Inheritance of Stockiness in Ponderosa Pine Families, by Roy R. Silen and Kenneth E. Rowe (16)

Because stockiness in trees means more wood volume, tree breeders would find it helpful to know whether this trait is inherited and should be considered in selecting parent trees for a tree improvement program.

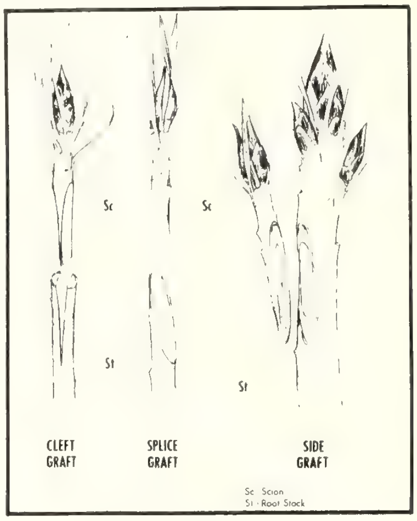
In this study, seed was collected from selected pairs of stocky and slender mature ponderosa pine and planted. Measurements taken after 3 years' growth of the seedling crosses tentatively verified stockiness as an inherited trait. Long-term observation is needed to see whether the early findings persist. So far, results suggest that tree breeders can improve volume growth by selecting parents for stockiness as well as height.



Seedling height and diameter for a stocky and a slender pair.

Effect of Graft Type on 6-month Scion Survival of Field Grown Douglas-fir Grafts, by Donald Copes (17)

Thousands of grafts are made each year to establish and maintain Douglas-fir seed orchards. Each orchardist soon adopts the graft type he thinks is best, easiest, or quickest to make. Copes evaluated three types of graft (top—cleft, splice, and side) for improving first-year survival. He found that the type of graft did not significantly influence survival, provided 80 mm or more of cambial contact connected the stock and the material being grafted.



Stock and scions prepared for the top-cleft, splice, and side graft types.

Effect of Date of Grafting on Survival in Douglas-fir, by Donald L. Copes (18)

Seed orchard operators try to anticipate the best time of year for grafting. A field study of 1,300 grafts in western Oregon indicated that survival of 90 percent or better was obtained when Douglas-fir was grafted between early spring and mid-May. Grafting in September and October was especially unfavorable.

Effect of Annual Leader Pruning on Cone Production and Crown Development of Grafted Douglas-fir, by Donald L. Copes (20)

When grafted Douglas-fir trees grow 2 to 4 feet in height each year, the tops of the trees are soon difficult to reach for insect and disease control or pollination. Tall trees also make the operation of overhead irrigation systems difficult in seed orchards. A study begun in 1965 showed that pruning leaders every other year (after seed trees are 14 to 20 feet tall) is the best way to cope with the height problem without severely reducing cone production.

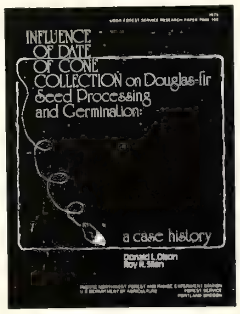
Several additional reports on grafting Douglas-fir in seed orchards, some of them quite technical, are listed in the bibliography (21).

Crown density values employed in rating pruned and unpruned trees are illustrated: A, very dense; B, dense; C, moderately dense; D, low density.

Influence of Date of Cone Collection on Douglas-fir Seed Processing and Germination: A Case History, by Donald L. Olson and Roy R. Silen (19)

Because of limited manpower, cone gathering to provide seed for tree nurseries is often begun as soon as cones appear ready. But if cones aren't sufficiently ripe, the seed is likely to be immature. Olson and Silen report some of the problems and costs of using immature seed: fewer seeds per cone, susceptibility to mold, more time spent by nursery workers, and poor germination in laboratory and nursery.

Low seed weight is a clue that the seed is immature. The authors recommend that seed lots suspected of immaturity be discarded, saved for use only when supplies of better seed are exhausted, or artifically ripened. The better way, of course, is to collect only mature cones.



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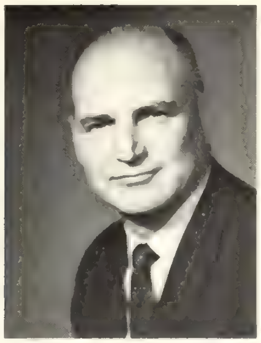
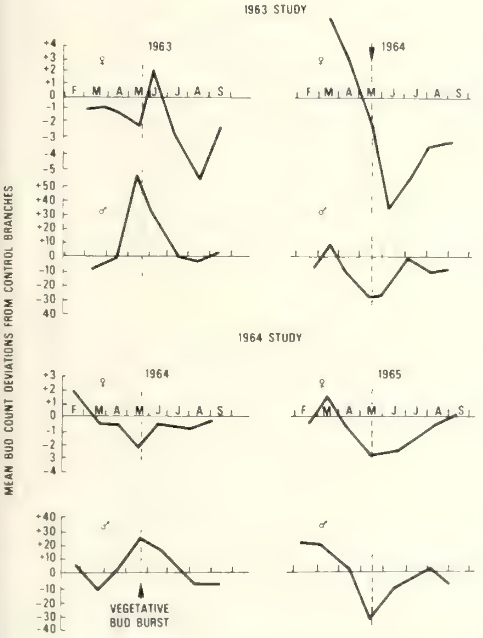
COLLECTION on Douglas-fir
Seed Processing
and Germination:
a case history
Donald L. Olson
Roy R. Silen



Roy Silen

First- and Second-season Effect on Douglas-fir Cone Initiation from a Single Shade Period, by Roy R. Silen (22)

In a very technical report, Silen discusses the relationship of weather changes (for example, shade) in producing a good cone crop. He wanted to find out if parts of the growing season—between February and September—were more important than others. What he found is that no single part of the season is crucial, but that shading applied for short intervals over a 27-month period can modify cone productivity. Certain portions of the period were more important than others.



Male and female bud count deviations over two seasons from branches shaded 1 month in two separate studies. Perpendicular lines indicate the time of vegetative bud burst.

Artificial Ripening of Douglas-fir Cones, by R.R. Silen (23)

Since Douglas-fir seed is seldom fully ripened on the tree before late August in the Pacific Northwest, the cone collecting period is often short. Lengthening of this period is a worthwhile goal, for it would permit better organization of cone collection and allow skilled personnel to collect more of the crop. Of three storage methods tried, cones stored at about 63° F. in damp peat moss gave full germination for collections made on August 1 and later.

The artificial ripening of seed in immature cones by some commercial method of damp storage appears possible for Douglas-fir. This may greatly lengthen the period of cone collection for this species, or provide a method of handling cones inadvertently picked before they are fully ripe.

Adaptational Requirements of Planting Stock, by Robert K. Campbell (24)

A note from a proceedings of the Western Forestry and Conservation Association meeting in 1975 discusses the adaptation of trees to given sites as the chief genetic requirement of planting stock. In the past, a zone classification system has been used to determine adaptation. All seedlings from within the zone are considered to be adapted, and all from without are nonadapted.

The author discusses a more realistic concept of adaptation and shows how adaptational requirements can influence decisions made by foresters before reforestation. The topic is discussed in four steps: (a) observations are given from the 60-year-old Douglas-fir heredity study to show what happens to a plantation that includes both "adapted" and "nonadapted" provenances; (b) adaptation is related to many facets of artificial regeneration, i.e., spacing, initial plantation success, etc.; (c) some differences are looked at in adaptation among Douglas-fir sources, especially sources from different elevations in the Cascades; and (d) the implications of these findings to plantation practices are discussed.

the available sampling systems required so many sample trees for acceptable accuracy that the idea of cutting them all down was unthinkable. Now, with a statistical sampling method called 3-P, a few sample trees are entirely adequate. For any given sale in which FBS cruising is used, anywhere from 50 to 200 sample trees are selected by 3-P sampling. The 3-P system was developed by Lew Grosenbaugh at the Forest Service's Pacific Southwest Forest and Range Experiment Station about 10 years ago. Under the system, the probability that a tree will be included in the sample is proportional to a quickly predicted ocular volume. Thus 3-P

BLM adopted the 3-P technique as soon as it became available in 1964. At first they measured the sample trees standing. It wasn't until 1968 that they started falling them. George Hartman, a forester with BLM in Portland, says they saw FBS cruising as a way to get highly accurate estimates without having to measure all the trees in a sale.

"The big benefit of FBS cruising is improved accuracy," according to Floyd Johnson, statistician (retired) at the PNW Station. Johnson, who worked with the Bureau of Land Management and the Forest Service to help get the system tested and put into use, finds FBS cruising intriguing. He says that FBS cruising is "a very practical idea," and that when accuracy is a major consideration, "FBS cruising has a lot of potential for doing the job better and cheaper than other cruising methods."

Johnson says that FBS cruising makes a lot of sense, particularly in defective old-growth timber in the West where there is a good chance of making a bad estimate. According to Johnson, FBS cruising gets rid of the cruiser's bias, so that only sampling error is left.

Johnson believes FBS cruising might also be especially useful for selective cutting in the pine region. With 3-P sampling, at least at present, the forester must visit every tree in the sale area and make a rough, "eyeball" estimate of volume. Only a few trees are actually measured. Because the forester must mark all trees to be cut in a selective harvest anyway, there's very little extra work involved in measuring the sample trees.

end
next "insight" page 55

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silviculture

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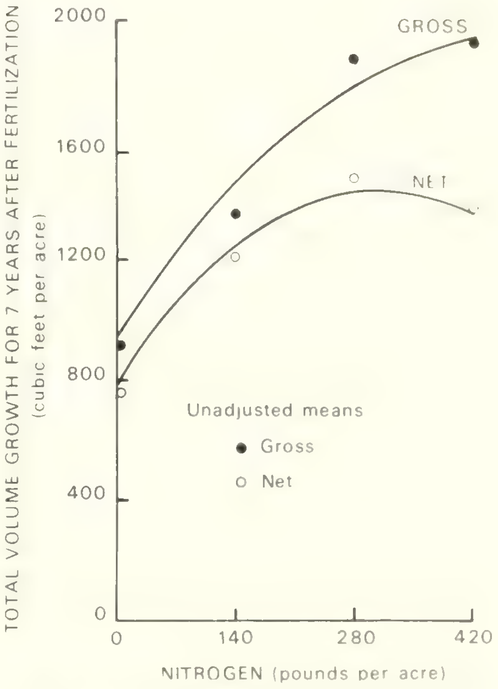
general

Intensive Management of Coastal Douglas-fir, by Curtis, Reukema, Silen, Fight, and Romancier (1)

West of the Cascades, the Pacific Northwest contains the most productive natural coniferous forests on earth. Since the first settlement, the most important tree has been Douglas-fir, a species remarkable for long life, rapid growth, relative freedom from insect and disease attack, and utility of its wood.

We are now in transition from the wild forests of the past to the managed forests of the future. Despite a very large growing stock, annual production rates in the wild forests were relatively low. Our new forests are capable of much higher production.

Intensive culture is really agronomic forestry. First, we must be able to get prompt and adequate regeneration of desired species. Second, we must protect the crop from insects, animals, and disease. Third, we can harvest the crop at ages which take advantage of the naturally high growth rates of young stands. Given these, we can further increase production over that of the wild forest by (a) control of spacing and competition, (b) soil fertility improvement, and (c) genetic improvement.



Effect of nitrogen fertilizer on cubic volume growth

silvicultural systems

Silvicultural Systems for the Major Forest Types of the United States, Agriculture Handbook No. 445 (2)

The current trend toward the establishment and care of forests for a wide combination of uses requires flexibility in forest culture and a knowledge of the silvicultural choices available to the resource manager. This publication summarizes, for each of 37 major forest types in the United States, the silvicultural systems that appear biologically feasible on the basis of present knowledge. Supporting information is given on the occurrence of the 37 forest types, the cultural requirements of the component species, and the biological factors that control the choice of silvicultural options. The text is arranged in regional sections suitable for reprinting.

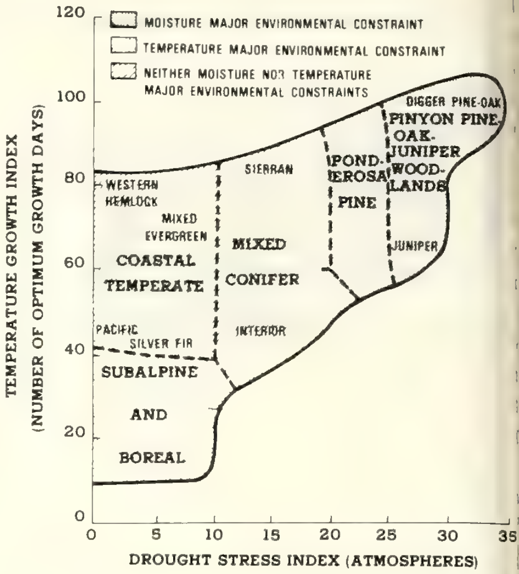
Pacific Northwest forest types discussed here include the following: western hemlock, Sitka spruce, coastal Douglas-fir, mixed conifers of southwestern Oregon, true fir, mountain hemlock, mixed pine-fir of eastern Oregon and Washington, northwestern ponderosa pine, interior Alaska white spruce, and interior Alaska hardwoods.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price is 80 cents domestic postpaid or 55 cents at the GPO Bookstore.

Effects of Various Harvesting Methods on Forest Regeneration, by Jerry F. Franklin and Dean S. DeBell (3)

For most forest types and species on most sites, foresters have wide latitude in choosing regeneration cutting methods insofar as ecological requirements of tree species are concerned. Few species or sites require uneven-age management under a selection system. Likewise, there is no ecological necessity for large patch or continuous clearcuttings to regenerate most types, species and sites including Douglas-fir; shelterwood or strip clearcut systems appear equally suitable for regeneration of most species on most sites. Selection systems can be used successfully for some major species, including certain southern pines. They also could be used for many others, provided that a change in species composition is acceptable. Ecological constraints do limit use of clearcuts on more severe sites, that is, those where moisture and temperature are major problems. With these exceptions, economic and social rather than ecological considerations appear to be the most important factors controlling selection of cutting systems.

Staggered-setting system of clearcut patches.

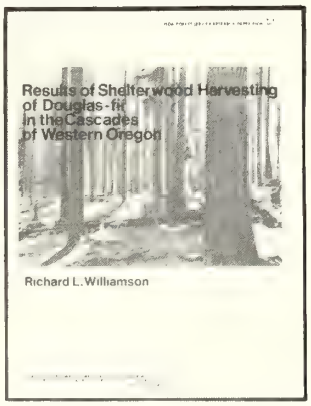


Place of Partial Cutting in Old-Growth Stands of the Douglas-fir Region, by Leo A. Isaac (4)

The partial-cutting system as studied and reported in this paper has not proven to be a successful method of harvesting Douglas-fir and converting virgin forests to new or thrifty stands on the average or better sites in the region. Even under conditions where it appears to offer promise, it is always associated with the danger of an unfavorable species change or loss from windfall, insects, or a combination of causes. Therefore, any plan for partial cut or selection cut in the Douglas-fir type should include a careful study of stand conditions in advance and provision for salvage in the event of severe loss or catastrophe.

See also a 1960 research note titled, *Behavior of Ground Vegetation Under a Partially Cut Stand of Douglas-fir,* by Kenneth W. Krueger (5).

Widely scattered Douglas fir in a dense stand of hemlock and silver fir just under commerical size. Large trees should not be cut until understory trees reach commercial size and injured trees can be salvaged.



Results of Shelterwood Harvesting of Douglas-fir in the Cascades of Western Oregon

Richard L. Williamson

Results of Shelterwood Harvesting of Douglas-fir in the Cascades of Western Oregon, by Richard L. Williamson (6)

Clearcutting Douglas-fir in the Pacific Northwest does not always result in successful regeneration, either natural or artificial. Where regeneration has failed, this has been due to such causes as temperature extremes and drought. Failures, primarily at higher elevations in the Oregon Cascades, led the Forest Service to try shelterwood harvesting, beginning in 1962, as a possible alternative to clearcutting. R.L. Williamson surveyed these shelterwood stands in the summer of 1970 with two main objectives:

1. To determine how successful shelterwood harvests were in securing natural regeneration.

2. To determine survival and condition of the shelterwood overstories during the regeneration period.

A total of 21 shelterwood cutting units were examined. All were at high elevations (3,000-5,200 feet) in the Cascades of western Oregon.

Results indicate that, in most cases, regeneration stocking is at least adequate by U.S. Forest Service Region 6 standards. These standards require a minimum of 250 uniformly distributed 4-year-old trees per acre, or greater numbers of younger trees. Satisfactory stocking in two shelterwood units was particularly gratifying to Williamson because he had personally made stocking surveys in the mid-1950's in some nearby older clearcuts which had experienced repeated plantation failures. These repeated failures indicated particularly severe local environmental conditions, which shelterwood harvesting apparently mitigated.

Results of Shelterwood Cutting in Western Hemlock, by Richard L. Williamson and Robert H. Ruth (7)

As a result of a shelterwood study in western hemlock, scientists conclude that shelterwood harvest is a viable alternative to clearcutting in that species.

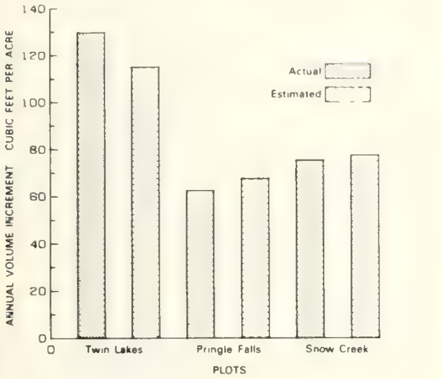
For the study, 12 shelterwood densities, ranging from 38 to 235 square feet of basal area per acre, were created in a 60-year-old stand. Eleven years after the first cut there were ample young seedlings at all cutting levels. In fact, the areas were overstocked. Other factors noted by the researchers included the following: (a) brush was adequately controlled by overstory densities of at least 90 square feet of basal area, (b) volume growth of the overstory trees was approximately proportional to the number of trees left, and (c) based on clearcutting experience in hemlock, shelterwood harvest was probably not essential for successful regeneration at this site.

Lodgepole Pine Symposium Summarized

Proceedings of a symposium on "Management of Lodgepole Pine Ecosystems" give valuable information on how to manage lodgepole pine in Oregon. The proceedings were edited by David M. Baumgartner and published in 1975 by Washington State University Cooperative Extension Service, Pullman, Washington 99163. Requests for the proceedings should be sent to that address.

We do have, however, copies of three reprints of papers given by PNW Experiment Station scientists. They include the following:

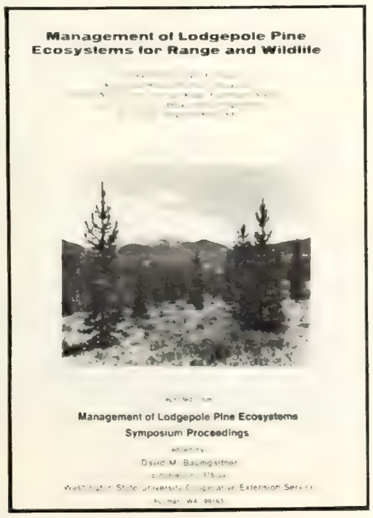
Gross Yield of Central Oregon Lodgepole Pine, by Walter G. Dahms (8). The paper includes yield estimates, site index estimating curves, and height-growth curves.



Comparison of actual and estimated gross volume increment from three sets of permanent sample plots. From Dahms (8).

Water Relations and Photosynthesis in Lodgepole Pine, by W. Lopushinsky (9). Presents available data on water relations and photosynthesis.

Management of Lodgepole Pine Ecosystems for Range and Wildlife, by J. Edward Dealy (10). Discusses the effect of lodgepole pine management on wildlife habitat (particularly mule deer and Rocky Mountain elk) and range for cattle.



Management of Lodgepole Pine Ecosystems for Range and Wildlife

Management of Lodgepole Pine Ecosystems Symposium Proceedings

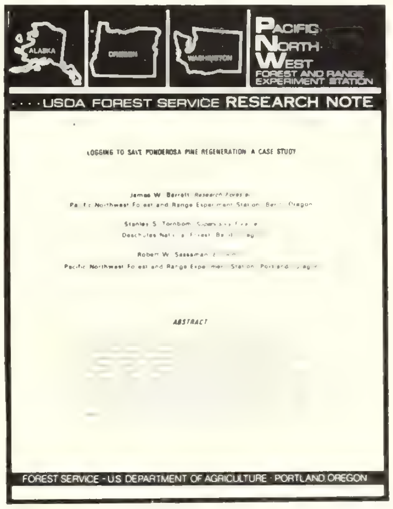
David M. Baumgartner

Washington State University Cooperative Extension Service

Logging to Save Ponderosa Pine Regeneration: A Case Study, by Barrett, Tornbom, and Sassaman (11)

Sapling-sized ponderosa pine trees can be saved from destruction during logging by marking the trees with paint. Marking the trees also aided in the systematic disposal of logging slash. After logging and slash disposal, at least 180 crop trees per acre were left on 75 percent of an area in the Pringle Falls Experimental Forest.

There are several million acres of ponderosa pine land in the Pacific Northwest where the incentive to save the understory is great. Trees that are from 1 to 8 inches in diameter and 6 to 30 feet in height might be equivalent to 10- to 30-year-old planted trees. If enough trees could be saved to adequately stock the area, the job of site preparation and planting could be eliminated, and the trees would be further along toward maturity. Furthermore, the area would be stocked with well-established trees highly adapted to the site through many generations of natural selection. Also, the land could be kept green, and the objectionable denuded appearance that results from clearcutting and planting avoided.



PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

LOGGING TO SAVE PONDEROSA PINE REGENERATION: A CASE STUDY

James W. Barrett

Pacific Northwest Forest and Range Experiment Station

Stanley S. Tornbom

Robert W. Sassaman

ABSTRACT

FOREST SERVICE - US DEPARTMENT OF AGRICULTURE - PORTLAND OREGON

reforestation

Publications on Reforestation

A bibliography of selected publications on reforestation has been published by the Western Forestry and Conservation Association since 1964. References include: (a) all publications on reforestation in the western United States and Canada; (b) selections from worldwide literature that contain information about western species; and (c) other publications of general interest, timeliness, or broad applicability. Ask for the *Listing of Selected Publications on Reforestation,* by year (12).

SMALL STREAMS AND FISH HABITAT

by Louise Parker

Phyllis Weber is an enthusiastic student of nature. A resident of Seattle, Washington, the perky 26-year-old University of Washington graduate student spent the summer of 1975 in Alaska studying the effect of logging on small streams. Her work was done as partial requirement for a master's degree in forestry at the University of Washington.

The study area is at Corner Bay, southwest of Juneau in the Tongass National Forest. Trees there are mature coastal Sitka spruce and hemlock, around 400 years old. Streams are small and typical of the watercourses that punctuate many mountainous regions in coastal Alaska. They have the added importance of being rearing areas for young Dolly Varden and coho salmon. Information gained from studying the environment of those small streams will help forest managers improve logging practices, especially as they relate to fish habitat.

Study plots are located in both undisturbed forest and in areas that have recently been clearcut. Data are being gathered on many environmental factors, including air and water temperature, aquatic insects, and plant communities.

From her work so far, Phyllis offers several observations about good logging practices. As far as fish habitat is concerned, the best logging practice insures that:

- *Debris is kept from streams, even the smallest tributaries. Nearly all provide some habitat for fish.*
- *Culverts are properly placed to enable passage of fish even during the lowest streamflow. Sometimes culverts are placed properly in the beginning, but end up being ineffective because of settling of the fill material.*
- *Clearcuts are designed to minimize the amount of stream that is exposed. Shrubs and other plants left along streambanks also help shade the stream and maintain proper water temperature.*

When steep slopes must be logged, Phyllis believes that the best system is skyline logging. She bases this observation on her previous Forest Service experience with PNW's logging engineering research unit, which is developing improved logging systems.

natural

Reproductive Habits of Douglas-fir, by Leo A. Isaac (13)

Every forester in the Douglas-fir region should either read or be familiar with the contents of Leo Isaac's early (1943) paper on regeneration of Douglas-fir. As Thornton Munger, the first director of the Experiment Station, once said, Isaac "was an exceedingly sharp observer. He could see little 1-year-old seedlings when the ordinary person would pass them by. . . ."

Isaac summarizes his many years of observations in this 107-page report published by the Charles Lathrop Pack Forestry Foundation. The report is now extremely rare, but good libraries should be able to get a copy. Those who have access to the PACFORNET resource library may want to have copies made. Copies are NOT available from the Experiment Station.

In the report, Isaac discusses everything from seed supply, seedling establishment, and the effect of soils, climate, vegetation cover, to a variety of environmental factors on regeneration of Douglas-fir. Silvicultural treatments, including the single seed tree method, seeding from the side, and partial cutting are also discussed.

The summary paragraph of the paper is still a good rule to follow: "Conditions within the Douglas-fir type are so varied that simple, specific rules cannot be set forth for securing regeneration over large areas, either in the management of young stands or the harvesting of over-mature virgin forests. However, careful study of all local factors coupled with an earnest application of the findings set forth in this publication will produce far more satisfactory regeneration than has been obtained in the Douglas-fir region in the past."

As has been said often, a number of errors in forest management in the Douglas-fir region could have been avoided if foresters involved had only been thoroughly familiar with the work of Leo Isaac. This paper and the following summary are two good ones.

Factors Affecting Establishment of Douglas-fir Seedlings, by Leo A. Isaac (14)

The plant association in the Douglas-fir region, when destroyed by fire, goes through four distinct stages of succession before it reaches the climax type, unless again interrupted by fire or logging. These stages are the "moss-liverwort," "weed-brush," "intolerant even-aged Douglas-fir," and the "tolerant all-aged hemlock-balsam fir;" the last named, so far as is known, will persist. The weed-brush stage is most subject to fire, and successive fires do prolong and can perpetuate this stage.

Colonies of exotic species are upsetting natural succession in some localities because they are unpalatable and more vigorous than native species. Grazing tends to eliminate palatable species and favors others like the exotics, bracken, and brush; however, many grasses have been introduced that have become naturalized and have improved grazing.

The underground parts of some virgin forest ground-cover species survive fires and form a minor part of the weed-brush stage; the remainder is made up of invading species, the most important of which are bracken, fireweed, blackberry, and snowbrush. Some species run their course and disappear, while others persist until they are crowded out by more vigorous brush cover and the oncoming forest.

Light cover is beneficial to coniferous seedlings but heavy cover is detrimental, and the weed-brush stage often develops a density that practically prohibits forest regeneration.

Successive fires impoverish the soil, favor the herbaceous species, retard the brush species, and eliminate from the succession the coniferous seedlings that would go to make up the new forest.

This report, too, is extremely rare. In fact, we couldn't find a copy locally to review. But the article was summarized by Isaac in a 1940 *Journal of Forestry* article which should be easy to find: 1940, Vegetative succession following logging in the Douglas-fir region with special reference to fire. Jour. of For. 38:716-721.

GERMINATION AND EARLY GROWTH OF COASTAL TREE SPECIES ON ORGANIC SEED BEDS

Germination and Early Growth of Coastal Tree Species on Organic Seed Beds, by Don Minore (15)

Shelterwood cutting is increasing in coastal forests of the Pacific Northwest, primarily because of scenic values. This means that foresters need to know more about the effects of shade and seed beds on establishment and growth of various tree species in that region—Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder.

Results of three studies indicate that shade is an important factor in determining where young seedlings will become established and how well they grow once established. For example, in heavy and moderate shade, most coastal conifer seedlings will become established on rotten logs, rather than on the duff-covered forest floor. In light shade, both materials are excellent seed beds. But under full sunlight, neither organic seed bed is very good.

Not only are more seedlings established under heavy shade on rotten logs but they also grow better there—even though more nutrients are available in duff than in rotten wood. The apparent paradox is explained by the fact that more duff accumulates on tops of rotten logs than on the forest floor.

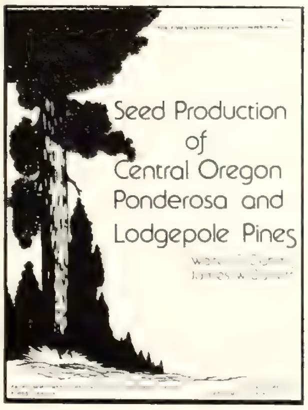
Where light shelterwood will result in a shaded seed bed, rotten wood and duff should be preserved. This will benefit all conifer species by providing extra nutrients for the short-rooted seedlings produced under low-light conditions.

Uprooted hemlock seedling with roots embedded in buried rotten wood.

Dispersal of Lodgepole Pine Seed Into Clear-cut Patches, by Walter G. Dahms (16)

In south-central Oregon, lodgepole pine produces good seed crops in most years. But unlike lodgepole pine in the Rocky Mountain region, the cones in Oregon tend to release their seed fairly promptly following ripening. In the Rockies, lodgepole pine cones are "serotinous," meaning they hold their seed for several years or until opened by fire. As a result, natural regeneration of clearcuttings depends largely on seeds that come from surrounding timber.

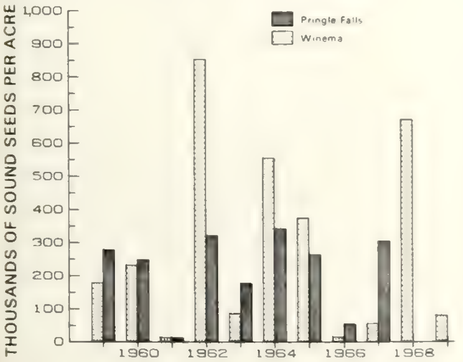
The number of seeds dispersed into clearcuttings falls off very rapidly from the timber's edge and reaches a very low level at distances beyond 200 feet. Consequently, foresters should restrict the width of clearcut strips or blocks to about 400 feet, allowing trees on either side to seed into the center of the clearcut.



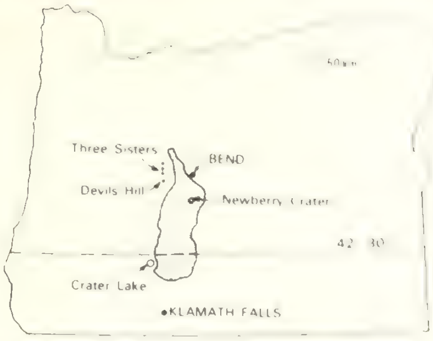
Seed Production of Central Oregon Ponderosa and Lodgepole Pines

Seed Production of Central Oregon Ponderosa and Lodgepole Pines, by Walter G. Dahms and James W. Barrett (17)

From studies begun in 1953, researchers have learned much about the natural seed production of two central Oregon trees—ponderosa and lodgepole pine. Their observations indicate that lodgepole is a more prolific seeder than ponderosa pine. Lodgepole produced enough sound seed to get a satisfactory crop of seedlings 3 years out of 4. Ponderosa pine produced only five good seed crops during a 22-year period.



Number of sound lodgepole pine seeds per acre on the Winema and Pringle Falls area.



Approximate boundary of the pumice-mantled plateau in Oregon

Soil Temperatures and Natural Forest Regeneration in South-Central Oregon, by P.H. Cochran (18)

Part of south-central Oregon, that area west of Bend and south to Crater Lake, is covered by a mantle of pumice that resulted from the eruption of Mount Mazama and other mountains thousands of years ago.

This region supports extensive forests of ponderosa and lodgepole pine. Usually lodgepole occurs in pure stands on flats and in basins, while ponderosa or a mixture of the two species dominates the higher ground. This distribution apparently results because lodgepole seedlings are more tolerant to low night temperatures so they grow better in "frost pockets."

Also within this area are many "pumice deserts" which are poorly stocked or nonstocked. Since mismanagement of forest stands could sharply increase this desert area, proper cutting methods and reforestation procedures are essential. Researchers note that natural regeneration is most successful when an ideal sequence of events occurs: a good seed year, followed by a warm, moist spring; a cool, wet summer; and an early snowfall.

Since the ideal can't always be counted on, natural regeneration can be promoted by clearcutting timber in strips less than two tree heights wide, leaving trees in a shelterwood cut no more than one-half tree height apart, and leaving some untreated slash as ground cover. Another alternative is to depend more on a planting program.

For an early report on the same subject, see also Research Note PNW-204, *Natural Regeneration of Lodgepole Pine in South Central Oregon,* by P.H. Cochran (19).

[illegible]

In her field work, Phyllis works closely with Art Bloom, a fisheries biologist at the Juneau Lab. "The problem in Alaska is recognizing the importance of small streams as fish producers," Bloom says. "Most people understand the role that larger streams play in salmon spawning. But few know that the fish, especially coho salmon, use the very tiny feeder streams as rearing areas."

Research in the 1950's, on Prince of Wales Island, indicated that clearcutting did not adversely affect the salmon spawning habitat—at least with the techniques used, no damage was detected. There was a moderate increase in stream temperature in the fall following logging. Streamflow and sedimentation also increased following logging, but no one knew what effect that may have had on fish habitat.

Researchers, including Bloom, now believe that very minor changes in environment do affect the fish and that the early research methods were not accurate enough to detect the small changes in temperature or sediment that might have affected eggs or young fish.

Bloom has some studies underway in the tributaries of the Kadashan River a few miles west of Corner Bay. This is one of the best salmon-producing streams in southeast Alaska. He is studying fish rearing habitat, looking at factors such as physical characteristics of streams, streamside vegetation, and food available for the fish. Bloom is now preparing reports on this work. The research results will help provide management prescriptions for protecting fish habitat during and after logging.

"Logging does not have to be detrimental to the fishery resource," Bloom says. "It's a matter of how it's done."

During some stages of development (particularly the "eyed" stage or until about 2 weeks after fertilization) the fish are especially vulnerable to environmental changes. Very small changes in stream temperature or sediment can cause mortality.

Stream temperature is affected by the amount of vegetation along the streambanks. When an area is clearcut down to the edge of a stream, water temperature can go up as much as 10 to 20 degrees or more. This is important because an increase in temperature can affect spawning behavior, egg survival, and the survival and growth of fry. For one thing, fish eggs hatch according

Lodgepole Pine Cold Resistant

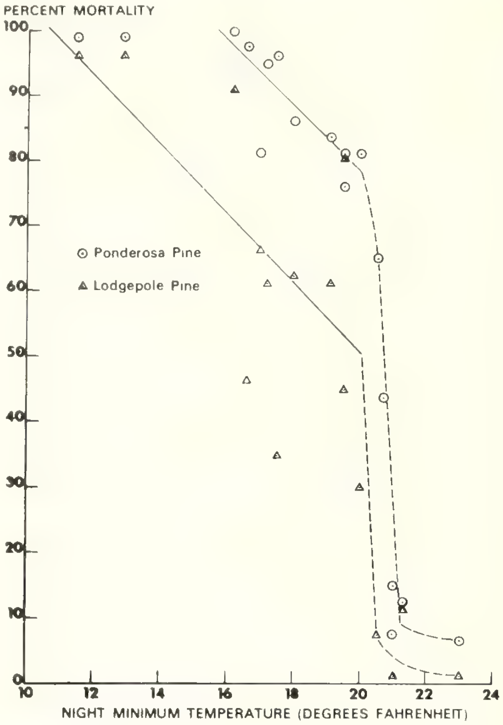
In trying to learn more about why lodgepole pine and ponderosa pine tend to segregate themselves in the pumice soil region of south-central Oregon, researchers conducted some studies to test the cold resistance of each.

What they found was interesting. In growth chamber studies, 36-day-old seedlings were exposed to night minimum temperatures of less than 23° F. As a result, more of the ponderosa pines died. The lodgepole was more frost-hardy.

Interesting to note that younger seedlings (22 days old) were more tolerant of low night temperatures than older seedlings. Prior exposure of seedlings to near-freezing levels also helped reduce the damage. Also, by the time seedlings were 2 months old, the difference between temperature tolerance of the species had disappeared.

Results support the hypothesis that the "frost pocket" distribution of lodgepole pine in a mosaic with ponderosa pine is partly due to the differing ability of the seedlings to withstand low night temperatures.

See *Tolerance of Lodgepole and Ponderosa Pine Seedlings to Low Night Temperatures,* by P.H. Cochran and Carl M. Berntsen (20).



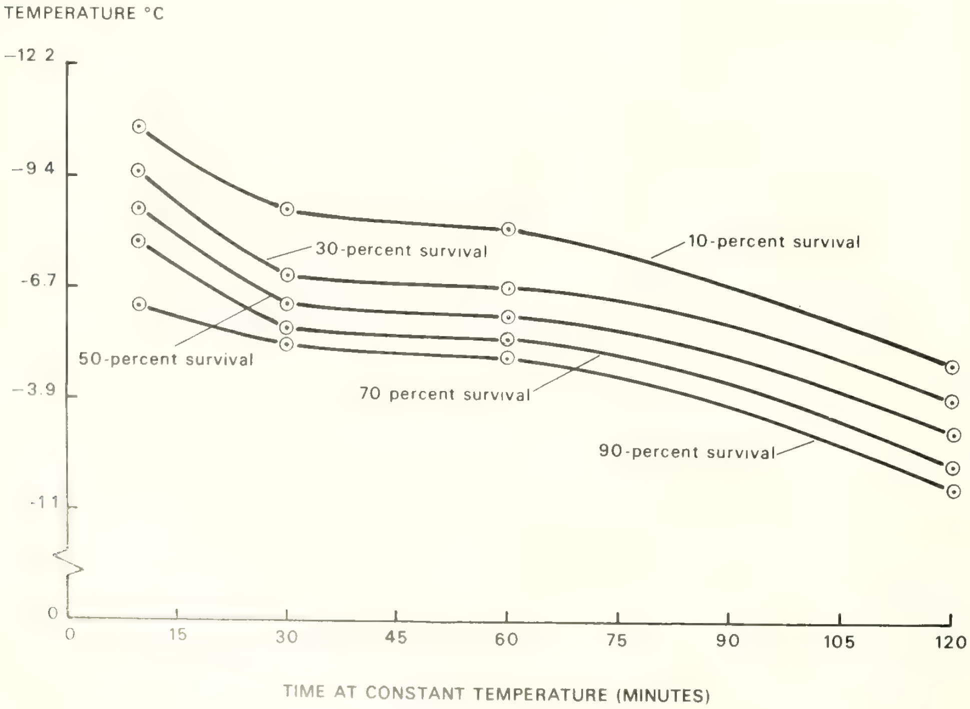
Mortality of ponderosa and lodgepole pine as related to night minimum temperature.

Freezing Kills Grand Fir

Temperatures lower than −5° C. can result in considerable mortality of newly germinated grand fir seedlings—if they are exposed longer than 10 minutes. Since temperatures this low are common in the spring in central Oregon, this can be a significant factor in causing grand fir mortality.

Low night temperatures are not likely to be a problem in the fall, however, because by then seedlings are more frost resistant. Also, in the fall temperatures do not generally drop below −18° C. or, if they do, not for very long.

Freezing Resistance of Hardened and Unhardened Grand Fir Seedlings, by K.W. Seidel (21).



"Isosurvival curves" of 10, 30, 50, 70 and 90 percent for 1 week old grand fir seedlings.

Frost Tolerance of Ponderosa and Lodgepole Pine, by Frank C. Sorensen and Richard S. Miles (22)

The cones and pollen catkins of lodgepole pine were much less damaged by a late spring frost than those of ponderosa pine at the same stage of development. Previous studies had reported that lodgepole is more tolerant of low temperatures as the seedlings emerge, and this species is found in frost pockets of central Oregon where ponderosa is not.

Soil Moisture and the Distribution of Lodgepole and Ponderosa Pine, by Robert F. Tarrant (23)

This report is a review of the literature on soil moisture and the distribution of lodgepole and ponderosa pine. Lodgepole pine had generally been thought of as a "weed" species. At times there had been proposals to get rid of the lodgepole and replace it with the economically superior ponderosa pine. These proposals were based on the assumption that lodgepole stands are the direct result of fire and represent encroachment onto ponderosa pine sites. A roundup of the pertinent literature helps eliminate some of these misconceptions.

seeding and planting

Ten-Year History of an Oregon Coastal Plantation, by Robert H. Ruth (24)

In 1941, the federal government acquired the Blodgett tract between Waldport and Yachats on the central Oregon coast. Although the region is highly productive timber land, it was not in good shape. The entire area was clearcut between 1919 and 1936, removing a stand of huge old-growth Douglas-fir, Sitka spruce, and western hemlock. Then the area burned over several times, eventually killing most of the seed trees. Tree planting was begun almost immediately after the tract was acquired by the government and continued until late 1944. By then, brush and alder had developed over the remainder of the area to a point where planting was impractical.

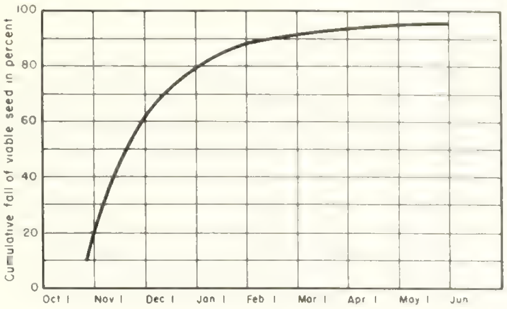
In 1943, a study area was established on the ridge near the center of the tract to test various species for planting on the site, survival of fresh and stored planting stock, effects of various planting techniques, and the influence of aspect.

The report describes what happened to trees in the study area during a 10-year period. Stocking averaged 581 trees per acre.

A 4-Year Record of Sitka Spruce and Western Hemlock Seed Fall, by Robert H. Ruth and Carl M. Berntsen (25)

Four years' measurement of seed fall in the spruce-hemlock type on the Cascade Head Experimental Forest indicates that an ample supply of seed is distributed over clearcut areas under staggered-setting cutting. The largest tract sampled was 81 acres; in spite of a seed crop failure in 1950, it received an average of 243,000 viable spruce and hemlock seeds per acre yearly on a high ridge near the center of the area. In the spruce-hemlock type it is apparently practical to clearcut fairly large openings and still depend upon adjacent stands for an adequate distribution of seed.

Spruce and hemlock seed fall consistently started during the last 10 days in October, usually when the first dry east wind occurred. Viability of seed averaged 55.5 percent.



Season of seed fall for Sitka spruce and western hemlock on the Cascade Head Experimental Forest

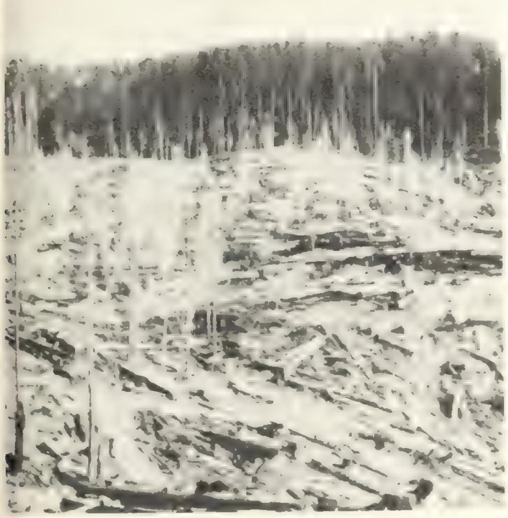
Sugar Pine Successful in Southwest Oregon

An older, but still useful research paper, describing the first pilot-scale direct seeding of sugar pine in southwestern Oregon. The project was carried out in an area that had been logged in the Umpqua National Forest near Tiller, Oregon, in 1951. Elevations in the 67-acre clearcut ranged from about 2,900 to 3,300 feet, with all aspects represented.

Control of seed-eating rodents was accomplished by three separate applications of baits before seeding. Seed was placed in the ground in November in spots spaced 4 x 8 feet apart.

A good stand of sugar pine resulted. At the end of the second year, a survey showed 72 percent stocking and 455 seedlings per acre. Germination and survival were generally better on exposed mineral soil.

A Successful Direct Seeding of Sugar Pine, by William I. Stein (26).



A view of the seeded area looking southeast from the north boundary.

Pumice Soils Limit Root Growth

In the pumice soil region of central Oregon, the physical characteristics of some soils—notably the C1 horizon of the Lapine soil—limit seedling development. Apparently several factors are involved—bridging of individual soil particles, the high percentage of air-filled pore space in the soil, the nonplasticity of the pumice material. They combine to create a soil condition that limits root proliferation and penetration.

The study results suggest that some comparisons should be made between machine and auger planting in this region. Auger planting might result in more rapid penetration of roots through the unweathered surface layers into the buried soil profile.

Pumice Particle Bridging and Nutrient Levels Affect Lodgepole and Ponderosa Pine Seedling Development, by P.H. Cochran (27).

Peroxide Not Recommended

Use of strong hydrogen peroxide as a seed treatment to speed germination is **not** recommended. Researchers used a 30-percent solution of hydrogen peroxide and compared its effect on seed with normal cold stratification. Subsequent growth of potted seedlings was measured after 7 weeks and after 1 year. Average size of the peroxide treated larch was significantly less than for the trees from stratified seed. In most cases, Douglas-fir and ponderosa pines also tended to be smaller when the seed was treated with strong peroxide.

See *Growth of Douglas-fir, Ponderosa Pine, and Western Larch Seedlings Following Seed Treatment with 30 Percent Hydrogen Peroxide,* by James W. Edgren and James M. Trappe (28).

to the amount of heat they have accumulated. If the temperature is higher than normal, the eggs hatch sooner. They might even hatch before there are enough natural foods available for them.

Too much sediment in the streambed can also cause mortality. One of the research problems has been to develop devices that are sensitive enough to detect small changes in bedload sediment. Since salmon eggs are laid in gravel on stream bottoms, a suitable gravel sampling device is necessary.

Unhappy with the devices available, Bloom's research technician, Bill Walkotten, invented an improved "gravel freeze sampler" using carbon dioxide to freeze a core of the streambed. The method is now being used by other researchers around the state.

The Walkotten sampler enables a biologist to remove a plug of frozen gravel from the streambed. To take a sample, a hollow copper probe is inserted in the streambed. The liquid carbon dioxide is then pumped into the probe. When the probe is pulled out again, a frozen section of streambed comes with it. A device to measure waterflow in the gravels is also being developed.

Geographic features and weather conditions make it difficult to conduct research in Alaska. For example, all of the study areas are at considerable distances from the Lab's Juneau headquarters. Kadashan Bay is 50 air miles away, as is Corner Bay. Young Bay, another study area, is somewhat closer, but is often less accessible by boat or airplane. Maybeso Creek valley, where early watershed studies were conducted, is 240 miles.

The effective working season, in this rainy, cold part of southeast Alaska, is from the end of May to mid or late September. Access is by helicopter, airplane, or boat. There are no roads or trails. For long-term studies, you really need to live where you work.

A few years ago, the researchers needed to move a truck and backhoe to Young Bay. It took four men 5 days with a tug and a barge to get the equipment moved. The cost of moving the equipment alone was $1,200.

In such an environment, with a small staff, research results come slowly. But the work is important, and the lessons learned so far have been of help to foresters planning timber harvest programs in the Tongass

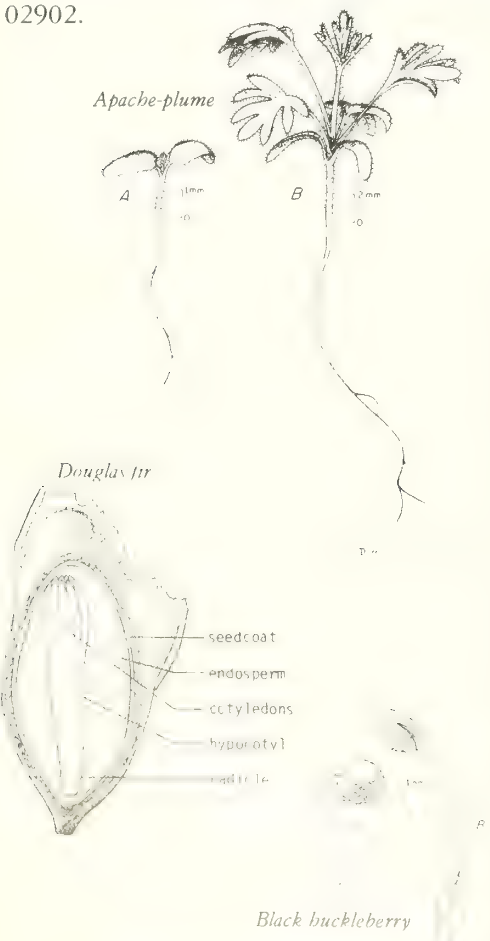
Seeds of Woody Plants in the United States, USDA Agriculture Handbook No. 450 (29)

An updated handbook that serves as a basic and necessary reference for anyone working with seeds of forest trees or other woody plants in the United States. Part I of the book covers principles and general methods of producing and handling seeds in 8 chapters:

I. Seed Biology
II. Principles of Genetic Improvement of Seed
III. Production of Genetically Improved Seed
IV. Pollen Handling
V. Harvesting, Processing, and Storage of Fruits and Seeds
VI. Presowing Treatment of Seed to Speed Germination
VII. Seed Testing
VIII. Tree-Seed Marketing Controls

Part II is a compilation of data on 188 genera of woody plants including flowering and fruiting dates, seed processing methods, storage conditions, seed yields and weights, methods of breaking seed dormancy, germination tests, and a large collection of fruit and seed photographs.

The book is for sale from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 at a cost of $13.60. Order Stock Number 0100-02902.



An Increase in Conifer Seedling Survival and Vigor on an East Cascade Slope With a Soil Fumigant, by G.O. Klock (30)

Biotic factors may be restricting conifer seedling development in some soils east of the Cascades. Study results at one planting site indicate that soil fumigation can improve seedling survival. Survival of 2-year-old Douglas-fir seedlings was 45 percent on nonfumigated plots; 92 percent on plots fumigated with methyl bromide.

Fumigation is not necessarily recommended, but this researcher believes more research should be done to determine **why** fumigation resulted in the positive response.

Food Reserves and Seasonal Growth of Douglas-fir Seedlings, by Kenneth W. Krueger and James M. Trappe (31)

Stage of seedling growth and development should govern the timing of many nursery operations. In this study, seasonal relationships were determined between food reserves and growth of Douglas-fir seedlings.

Rapid root growth both preceded and followed the period of rapid top growth. Concentrations of certain sugars also followed seasonal patterns and, in some instances, were correlated with increased root activity. Concentrations of fat and protein changed little with season.

These results provide physiological evidence on the need to lift seedlings in the nursery at the right time. Late fall lifting allows sufficient time for buildup of food reserves. Spring-lifted stock should be dug prior to the surge of root activity. Adequacy of other nursery practices can also be analyzed by information provided by this type of fundamental study of seedling processes.

Relationship of Shoot-Root Ratio to Survival and Growth of Outplanted Douglas-fir and Ponderosa Pine Seedlings, by W. Lopushinsky and T. Beebe (32)

What effect do the amount of roots and height of top have on survival and growth of conifer seedlings? The answer comes from a study carried out in north-central Washington.

Two-year-old Douglas-fir and ponderosa pine seedlings with three top heights, and with either large or small roots, were planted in a burned-over area. The first-year survival of fir seedlings with large roots was 22 to 26 percent higher than survival of seedlings with small roots. Pine survival was increased 5 to 15 percent. Shoot growth (increase in shoot mass) of large-rooted fir and pine seedlings was as much as 2.1 and 4.8 times, respectively, that of small-rooted seedlings. Height growth of both fir and pine seedlings with large roots was 1.2 to 1.7 times that of seedlings with small roots. Weather during the year was cooler and moister than most years, apparently accounting for the relatively high survival of most seedlings.

nursery practices

Nursery Fertilization of Douglas-fir Seedlings With Different Forms of Nitrogen, by Radwan, Crouch, and Ward (33)

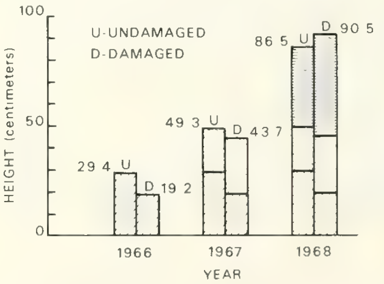
Three commercial fertilizers—ammonium sulfate, calcium nitrate, and urea—were tested to determine the relative values of ammonium, nitrate, and urea as nitrogen sources for Douglas-fir seedlings. The seedlings were grown at a forest tree nursery in western Washington, and the fertilizers were broadcast at 50 pounds nitrogen per acre in May and again in September. Seedling growth in the nursery and outplanting performance of the trees fertilized with nitrate and urea were essentially the same and superior to the ammonium treatment.

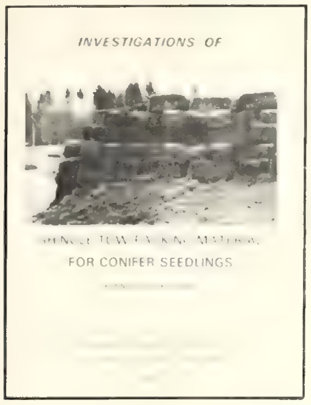
Growth of Frost-Damaged Douglas-fir Seedlings, by James W. Edgren (34)

Douglas-fir seedlings recently damaged by frost in the nursery should not be culled too heavily or seedlings with excellent juvenile growth potential will be discarded.

In a study at the Wind River Nursery, seedlings that had been hit by a hard frost in September 1965 were planted the same fall and next spring. Both seedlings that appeared damaged and those that did not were planted. Height growth of these seedlings over the next three seasons indicated that:

1. Some damage to Douglas-fir seedlings is hidden and can't be identified visually for many months,
2. Even when obvious, damage may not handicap future seedling growth,
3. Subsequent growth seems affected most when seedlings are lifted soon after being frosted, and
4. Multiple tops resulting from frost damage may be relatively unimportant.





INVESTIGATIONS OF

FOR CONIFER SEEDLINGS

Investigations of Shingle Tow Packing Material for Conifer Seedlings, by Kenneth W. Krueger (35)

Shingle tow, the stringy by-product from the manufacture of western redcedar shingles, has been used since about 1915 to keep seedling roots moist during shipment. For decades, it was the most commonly used material for packing trees for shipment from Pacific Northwest forest nurseries.

Shingle tow has not been without its critics, though. Unexplained seedling mortality during the first season after outplanting has been frequent in the Pacific Northwest. While there are many possible causes for such mortality, shingle tow has sometimes been suspect. In fact, some of the chemicals that leach from shingle tow are know to be toxic to Douglas-fir seedlings.

But are they toxic enough to cause large-scale mortality under the conditions of use? Unlikely, according to this report. But the concerns will probably persist, especially when plantation failures occur.

Sizing Seed Reduces Variability in Sowing Ponderosa Pine, by James W. Edgren and Charles A. Bigelow (36)

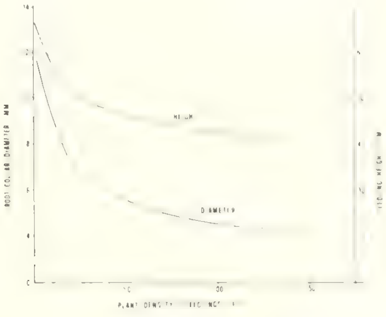
What effect does sorting seed by size have on the uniformity of sowing in the nursery? The answer to that question comes from a study at the Bend Forest Nursery.

Results indicate that sorting seed into size classes will improve seeder performance. Sowing rates for small seeds were more variable than for medium and large seeds. However, even medium and large seeds were not sown uniformly enough. Because seedling size is influenced by seed size, seedling density and distribution, the authors recommend that: (a) the actual contribution of small seed to the reforestation program be investigated, and (b) a seeder should be designed which ensures more uniform sowing.

Seedbed Density Influences Height, Diameter, and Dry Weight of 3-0 Douglas-fir, by Boyd C. Wilson and Robert K. Campbell (37)

Fairly large seedlings are needed in order to reforest many planting sites. These trees are usually produced by growing trees 2 years in a nursery seedbed and 1 year in a transplant bed, thus 2-1 stock. It might be cheaper, however, to grow the seedlings 3 years in the seedbed and thereby avoid transplanting.

Past observation has suggested that the growth of seedlings is greatly influenced by seedbed density. So a study was conducted at different spacings in the nursery, with the following conclusions: (a) spacing affects both height and diameter of seedlings; (b) Douglas-fir 3-0 seedlings do not have the same characteristics as 2-1 or 1-2 transplants; (c) Douglas-fir 3-0 seedlings use more bed space than transplants but are cheaper; (d) height and diameter of the seedlings can be used to predict dry weight of roots and tops; (e) with 3-0 planting stock, the top/root ratio is not likely to fall below 2.6; and (f) growing Douglas-fir 3-0 seedlings at 8-10 seedlings per square foot is suggested in order to produce optimum planting stock.



Relationship of seedbed density to seedling height and diameter of 3-0 Douglas-fir

Douglas-fir 2+0 Nursery Stock Size and First-Year Field Height Growth in Relation to Seed Bed Density, by James W. Edgren (38)

A preliminary account of the effects of seed bed density on seedling size and survival, this report points out the striking effect of bed density on diameter of the seedlings in the nursery and eventually on height growth in the forest.

Although additional studies must be made, it now appears that seedlings are too dense in the nursery at 40 per square foot.

Jim Edgren

National Forest. The fisheries work is conducted in cooperation with the Alaska Region of the Forest Service.

Don Schmiege, who heads the research program in Juneau, points out that the whole coast of southeast Alaska is important for fisheries. There are literally thousands of salmon-producing streams that run through forested watersheds. Land management practices in coastal Alaska can have a significant effect on the fisheries resource.

"It's the fresh-water habitat here we're interested in," Schmiege says. Other agencies, such as the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service, have responsibility for keeping accurate fish counts and for research on saltwater habitat.

No one knows for sure just what effect logging has on salmon production. Salmon catches have fallen off dramatically since about 1945. Many people believe the real problem is overfishing—not just of salmon, but also fish the salmon eat, such as herring. But the responsibility of land management agencies is to keep the habitat as productive as possible.

Habitat improvement research is also possible in the future. "There are many things that might be done to improve the fish habitat," Schmiege says. This might include removal of log jams, installation of fish ladders around natural barriers, and "riffle sifting" to rid the gravels of excessive sediment.

end

DESIGNING WITH DESK-TOP CALCULATORS
by Louise Parker

The PNW Experiment Station's Forest Engineering Laboratory in Seattle, Washington, has achieved a major advancement in logging engineering technology by using desk-top calculators. The compact Hewlett Packard 9830 calculator, together with a high-speed printer, electronic digitizer, and plotter, can now be programmed for road planning and harvest unit design.

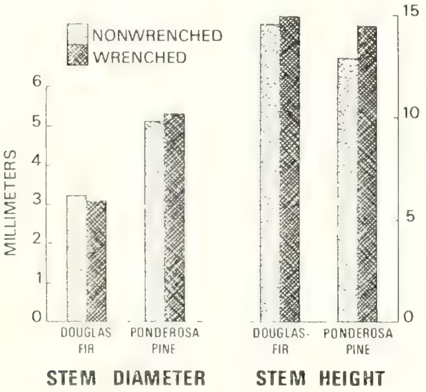
The basic cost of the system runs about $20,000. But even in today's inflated economy, that buys a lot of analytic and design

Wrenching—Recent Developments in an Old Technique, by James W. Edgren (39)

If seedlings raised in forest nurseries develop efficient root systems, they are hardier and survive better when planted in the forest. Undercutting and wrenching—techniques to encourage fibrous rooting, prevent deep rooting, and limit height growth—have been used for many years. New combinations of these techniques are now under study in the Pacific Northwest.

Seedlings are first conditioned by undercutting, a procedure in which the tap roots are cut off by passing a sharp blade under the seedbed. This is followed by passing a thicker, broader, tilted blade beneath the seedbed (wrenching) one or more times to sever replacement tap roots and aerate the root zone.

Though pioneered in New Zealand nurseries with Monterey pine, similar techniques should prove useful in the Pacific Northwest on native species when the proper treatment interval is discovered. A preliminary test involving ponderosa pine and Douglas-fir is discussed.



Coating Materials Protect Douglas-fir and Noble Fir Seedlings Against Drying Conditions, by Peyton W. Owston and William I. Stein (40)

The roots of tree seedlings should not be allowed to dry out excessively between lifting in the nursery and planting. Several coating treatments have been used successfully to prevent drying out. Clay slurry, xanthan gum, and sodium alginate protected roots of freshly lifted Douglas-fir and noble fir seedlings during 40 minutes' exposure. Xanthan gum was best for Douglas-fir and clay slurry best for noble fir.

The treatments are not recommended for trees destined for storage. Treated seedlings stored for 8 weeks were under much higher moisture stress one month after planting than seedlings stored with sphagnum moss packing material.

Field Survival Poor for Stored and Heeled-In Ponderosa Pine Seedlings, by James W. Edgren (41)

From a bad experience, the result of a premature lifting of several thousand ponderosa pine seedlings from the nursery in mid-November of 1968, has come some good advice—don't do it again.

The 3-0 seedlings were accidentally lifted, then put into cold storage or stored and later heeled-in until they could be planted in the spring. Storage and storage plus heeling-in had adverse effects on the seedlings. A year after planting, survival was best (57 percent) in the control group of trees planted immediately after lifting in the spring, poorest (18 percent) in the group stored longest, and intermediate (24 to 32 percent) in the trees stored and later heeled in.

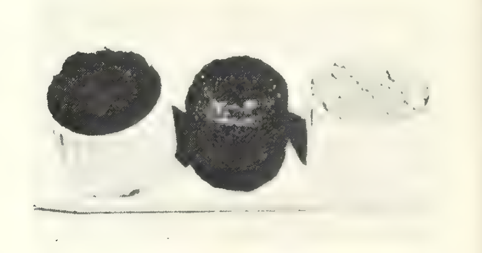
The trees were planted in southwest Oregon, where sites are normally hot, dry, and difficult. But length of storage is also important for seedling survival in other parts of the West.

Peat Proves Superior Medium for Douglas-fir Seedling Growth, by James W. Edgren (42)

In one test, Douglas-fir seedlings grew considerably better in expanded Jiffy-7 peat pellets and crumbled peat than in nursery soil.

Lateral root length differences between seedlings growing in peat and soil were startling. Total length of lateral roots in soil was one-twentieth that in Jiffy-7 pellets and one-nineteenth that of crumbled peat.

Study results suggest that a high percentage of peat would be advantageous for producing Douglas-fir in containers.



Douglas-fir seedlings were grown in, left to right, crumbled peat, expanded Jiffy-7 pellets, and soil.

container seedlings

First-Year Performance of Douglas-fir and Noble Fir Outplanted in Large Containers, by Peyton W. Owston and William I. Stein (43)

First-year survival of Douglas-fir and noble fir seedlings can be improved substantially by outplanting in large containers in which the seedlings have previously grown. Growth of 2-year-old nursery-grown Douglas-fir and noble fir was compared with trees grown and planted in four types of containers: milk carton, cardboard tube, peat pot, and plastic-mesh tube.

First-season survival of containerized Douglas-fir averaged 95 percent compared with 83 percent for bare-root stock. Comparable figures for noble fir were 88 percent for containerized trees and 78 percent for bare-root stock.

Height growth was also substantially better for containerized seedlings. Douglas-fir growth averaged 8.1 cm compared to 2.8 cm for bare-root stock.

For further discussion of this work, see also *Field Performance of Containerized Seedlings in the Western United States*, by Peyton W. Owston (49).

Douglas-firs 2 months after potting in; left to right, milk carton, Weyerhaeuser tube, Fertil pot, and Conwed tube.

Cultural Techniques for Growing Containerized Seedlings, by Peyton W. Owston (44)

Containerized seedlings may never fully replace conventional bare-root stock in the West, but they can be used to solve special reforestation problems:

1. To provide stock at optimum times for high-elevation sites
2. To regenerate western hemlock
3. To quickly reforest areas unexpectedly denuded
4. To provide uniformly treated, high quality seedlings for genetic and reforestation tests.

Owston discusses several factors related to growing containerized seedlings, including environmental controls, containers, potting mixture, sowing, watering, fertilizing, and hardening-off.

A Suggested Method for Comparing Containerized and Bare-Root Seedling Performance on Forest Lands, by Peyton W. Owston and William I. Stein (45)

Containerized seedlings are being produced and planted by the millions on forest lands in the Pacific Northwest. Approximately 23 million were grown in Oregon and Washington greenhouses and nurseries in 1973. With more and more forest acres being planted with containerized stock, it is necessary to evaluate the success of containerized seedlings and develop guidelines for their use.

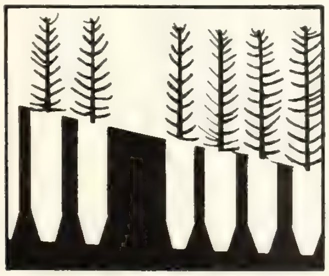
In this report, Owston and Stein describe procedures for making field comparisons of containerized and bare-root stock. Common use of the suggested methods will facilitate pooling of data and analyses. In addition, they seek to cooperate with organizations interested in evaluating containerized seedling performance.

Outlook for Container-Grown Seedling Use in Reforestation, by William I. Stein, Jerry L. Edwards, and Richard W. Tinus (46)

The reforestation methods of yesterday can no longer handle some of the challenges posed by modern forestry. The profession is turning increasingly to containerized seedlings. In 1973, the United States produced 963,105,000 trees for forest and windbarrier purposes. Of these, 3 percent (26 million) were grown in containers. Each year the number of container-grown seedlings increases.

In August 1974, about 350 people attended the North American Containerized Forest Tree Seedling Symposium at Denver, Colorado. In this synopsis, published in the *Journal of Forestry,* three Forest Service people describe the current containerized situation. The authors give some of the reasons for the move to container-grown nursery stock, expose some of the drawbacks, and point to important research needs.

Also available from that symposium are papers presented by Stein and by Owston (47 & 48).



Field Performance of Containerized Seedlings in the Western United States, by Peyton W. Owston (49)

The use of containerized stock is increasing dramatically in the western United States. As a result, field performance of these trees needs to be thoroughly evaluated. Operational flexibility gained by use of container trees is of questionable value if their survival and growth does not match or exceed performance of conventional bare-root stock.

Owston summarizes information from early trials where performance of bare-root and container stock is being compared. Small containerized Douglas-firs performed acceptably on sites that were not climatically harsh but did not match bare-root stock performance on hot, dry, south slopes. Large containerized stock may be suitable for a variety of uses but more needs to be known about cost and performance.

Bill Stein

Pete Owston

Why Use Container-Grown Seedlings? by William I. Stein and Peyton W. Owston (50)

Since 1970, use of container-grown conifer seedlings has increased dramatically in the western United States and Canada. For example, container seedling production in Oregon and Washington increased from less than 1 million to 43 million in just 5 years. During the same period, production of bare root stock also increased substantially.

There are important contrasts between container and bare-root seedlings. Container seedlings are generally younger and smaller, have a complete root system, are physically better protected, and do not lose contact with soil as do bare-root seedlings when moved from the nursery to the field. About twice as many container seedlings can be produced in the same amount of space in about half the time. Lot identification and seedling growth can be more closely controlled than for bare-root seedlings.

Field comparisons indicate that container grown seedlings often equal or exceed the survival of bare-root seedlings. The choice of stock to use hinges on relative cost, flexibility, management objectives, and individual circumstances. Container production and planting systems add a new dimension to the attainment of reforestation goals.

capability. According to Hilton Lysons, project leader at Seattle, the H-P 9830 system can significantly aid the logging engineer in expanding his design capability.

The Engineering Laboratory acquired their first desk-top calculator, an H-P 9100, in 1969 to use in skyline logging design. But they could see then that this approach had other applications in forestry—perhaps in road design, timber sale appraisal, and forest surveying. Since then, the group has developed seven computer programs for skyline engineering and five for road planning and design.

"Technology has a long history of advancing to meet the needs of the times," Lysons says. "Today's environmental constraints, plus the energy crisis, are forcing us to look at new ways to get our job done. The calculator lets the user properly consider the total systems requirements in developing the best logging and road plan."

Ward Carson, an engineer at the Laboratory, has used the calculator package to improve the design of skyline logging systems. He says recent skyline developments have promoted new interest in this method of logging.

Skyline systems are complex. The logging designer who opts for a skyline system is faced with a multitude of engineering problems, including anchors, allowable deflections, tensions, loads, topography, and the overall capability of the system under consideration. The chances for failure are almost legion and the hazards costly in terms of shutdowns, equipment failures, and hazards to life and property.

But skylines also have some distinct advantages. They can be used to log country that is steep and rugged without causing excessive environmental damage to the slope. Energy requirements are low, especially when compared to the heavy energy demands of helicopter logging, an alternate system for logging steep slopes.

In order to work with skylines, Carson says the logging designer must understand them thoroughly. In the past this was only achieved after long practice and experience in the field. "Now," says Carson, "that experience can be obtained by studying the system through the computer." He claims that any skyline design can now be handled on desk-top computers.

spacing and thinning

Considerable research has been done at the PNW Station on thinning and fertilization, and on their benefits when combined. Papers on thinning include articles that deal with the following species: lodgepole pine, western larch, ponderosa pine, and Douglas-fir.

douglas-fir

Guidelines for Precommercial Thinning of Douglas-fir, by Donald L. Reukema (51)

Production of merchantable wood in even aged Douglas-fir stands can be increased substantially by precommercial thinning. Considerations are discussed and procedures are recommended here. Guidelines for precommercial thinning depend on the size of tree that is wanted at the first commercial cut. In general, the larger the tree desired: (a) the fewer trees should be left after precommercial thinning, (b) the greater the age or tree size at which precommercial thinning is practical, and (c) the greater the gain in usable wood from precommercial thinning.

Also, generally, the longer the time required for a stand to reach commercial size without thinning, the greater the gains from precommercial thinning.

Fire Hazard from Precommercial Thinning of Ponderosa Pine, by George R. Fahnestock (52)

Precommercial thinning has become a major feature in management of ponderosa pine on the national forests of Oregon and Washington. Nearly 47,000 acres were thinned in 1966, up from 9,196 in 1959; and the upward trend appears certain to continue.

Thinning persumably increases wood production, but what effect does it have on fire hazard? The conclusion outlined is that thinning increases fire hazard for at least 5 years after cutting, but that the long-term result is reduced fire hazard.

Unthinned [illegible]

Dick Williamson

Cooperative Levels-of-Growing Stock Study in Douglas-fir, Report No. 1, by Richard L. Williamson and George R. Staebler (53)

Public and private agencies are cooperating in a study of eight thinning regimes in young Douglas-fir stands. The study is being carried out in western Oregon and Washington and on Vancouver Island in Canada. The regimes differ in the amount of basal area allowed to accrue in growing stock at each successive thinning. All regimes start with a common level-of-growing stock. Site quality of the areas varies from I through IV. Climatic and soil characteristics for each area and data for the stand after the initial thinning are described.

See also, Report No. 2 on the same study by John F. Bell and Alan B. Berg (53). Data from the first seven years shows that growth changes in the thinned stands were greater than expected.

See also Report No. 3 from trials in British Columbia, Canada. It's called *Levels of Growing Stock Cooperative Study in Douglas Fir in British Columbia,* by P.K. Diggle, BC-X-66, 1972, available from the Pacific Forest Research Centre, Canadian Forestry Service, Victoria, British Columbia.

Report No. 4 by Richard L. Williamson (54) described the status of three of the nine study areas maintained by the U.S. Forest Service.

In those areas, growth in all thinned stands was considerably below that in unthinned stands. The two older stands—27 and 32 years old—responded similarly to the calibration thinning. Growth percent of thinned stands was about 25 percent better than that of unthinned stands, however. The youngest stand, 19 years old at thinning, was so young that all trees were essentially free growing and little growth stimulation resulted. Thinning, however, enabled the trees to continue their free-growing condition as control stands began to show signs of competition.

So far, (this report was published in 1976) smaller trees (codominants) in thinned stands seem to be growing better than larger trees, but more time is needed to substantiate this finding.

Some Observations on Yield and Early Thinning in a Douglas-fir Plantation, by Norman P. Worthington (55)

A May 1961 article in the *Journal of Forestry* discusses the advantages of proper spacing in Douglas-fir.

At 31 years of age, measurements showed that yield in the plantation was markedly higher than if the trees had not been planted at exact spacings. Merchantable volume yields of 4,583 cubic feet and 17,614 board feet were obtained on a 150-foot site index —increases of 64 and 55 percent over yields from natural stands.

The greater growth of the planted trees is attributed to more exact spacing, which permits a rapid, less inhibited development of individual trees. As a result, plantation trees have larger and more numerous limbs than trees in natural stands, but it is believed their effect on lumber quality will be small. However, pruning would be practical if clear wood is desired.

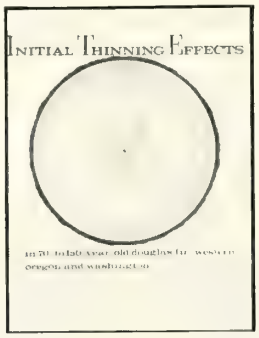
Initial Thinning Effects in Douglas-fir

Management guides are given for maximum production in vigorous, mature, essentially even-aged stands of Douglas-fir. The guides are primarily for stands 70 to 150 years old, but they may also be applied to older stands that are still vigorous.

The areas studied to obtain these guidelines are in western Oregon and Washington. In these studies, thinning resulted in the transfer of growth to fewer and better trees, and a more vigorous stand with less risk of mortality from bark beetles.

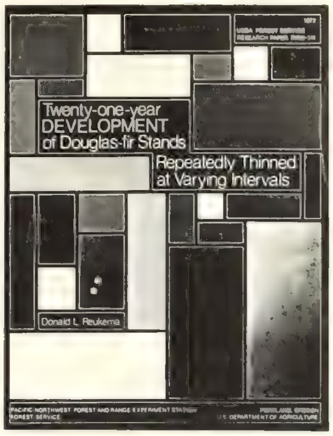
Recoverable cubic-volume growth, averaging 81 percent of normal gross growth, was recorded for up to 38 years with single thinnings and for 18 years with two thinnings. This percentage increases with stand age. In addition, there was a dramatic 61 percent reduction in loss caused by bark beetles and substantial reductions in losses from windthrow, breakage, and suppression.

Initial Thinning Effects in 70- to 150-year-old Douglas-fir—Western Oregon and Washington, by Richard L. Williamson and Frank E. Price (56).



INITIAL THINNING EFFECTS

in 70- to 150-year-old douglas-fir western oregon and washington



1977

USDA FOREST SERVICE RESEARCH PAPER

Twenty-one-year DEVELOPMENT of Douglas-fir Stands Repeatedly Thinned at Varying Intervals

Donald L. Reukema

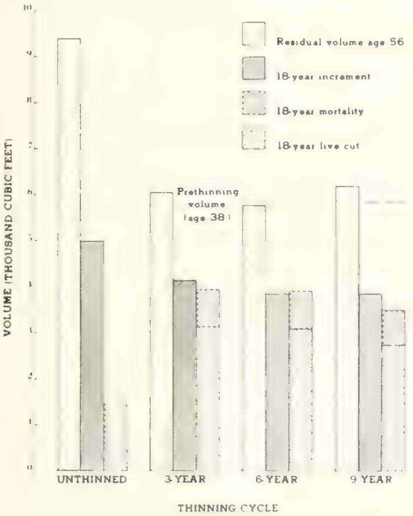
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE

PORTLAND, OREGON
U.S. DEPARTMENT OF AGRICULTURE

Twenty-One-Year Development of Douglas-fir Stands Repeatedly Thinned at Varying Intervals, by Donald L. Reukema (57)

Douglas-fir stands first thinned at about age 38 have been studied for 21 years. Four treatments were compared: no thinning, light thinning at 3-year intervals, moderate thinning at 6-year intervals, and heavy thinning at 9-year intervals.

Eighteen years after initial thinning, all the stands had about 65 percent of the volume they would have had without thinning. Gross growth in all thinned stands was about 20 percent less than in unthinned stands. There was less mortality in thinned stands, however, and that was enough to offset the growth loss. The primary benefit was an earlier harvest of products, not a substantial increase in total usable wood fiber.



Eighteen-year growth and yield, by treatment

Don Reukema

Forty-Year Development of Douglas-fir **Stands Planted at** Various Spacings, by Donald L. Reukema (58)

As the need for intensive forest management becomes more evident, the effect of initial plantation spacing and/or early thinning on stand development is of increasing interest and importance to the land manager. Douglas-fir stands planted in 1925 at Wind River, near Carson, Washington, have been observed periodically for over 40 years and provide an increasingly valuable record of the benefits derived from fairly wide, uniform spacing.

During recent years, diameter and height growth of even the 100 largest trees per acre and total basal area and cubic volume growth per acre have all been substantially greater on the wider spacings. Furthermore, a great share of the total volume produced in the closer spacings in not merchantable.

See also a 1970 report by Robert O. Curtis and Donald L. Reukema (59) that discusses *Crown Development and Site Estimates in a Douglas-fir Plantation Spacing Test.* Striking differences were noted among the various spacings in apparent site indices. These differences are attributed to reduced growth caused by competition rather than real site differences.

The authors caution that high initial density in low-site stands can lead to serious underestimates of potential productivity.

Commercial Thinning of Douglas-fir in The Pacific Northwest, by Norman P. Worthington and George R. Staebler (60)

This 124-page handbook may be a little old now (1961) but it is still the best summary on commercial thinning in Douglas-fir. Authors Worthington and Staebler discuss theory of thinning, its effects on forest management, how to carry out a thinning operation, the products produced, and costs and returns from commercial thinning. It's good background reading and a necessary first step for anyone considering thinning in Douglas-fir.

Small tractors are commonly used for skidding thinning products larger than can [illegible] by horses.

"A properly designed computer program puts the designer right into the act," Lysons says. "It enables him to quickly analyze the data, look at all alternatives, and then select the best possible design. That's the only way to meet the environmental constraints in an economical manner. Before the computer, the process of checking out all possible alternatives took so long that by the time you got one design thoroughly analyzed, you said the hell with it and let it go at that.

"The calculator provides the option of checking alternative systems quickly and of determining which system really fits the terrain. With the 9830, it takes about the same time to check all possible alternatives that it used to take to do one design by hand."

Doyle Burke, a logging engineer with the Seattle group, says that planning of timber access roads has always been one of the weak links in logging engineering. "The location and quality of commercial timber and elevation can be determined from aerial photos and topographic maps," Burke says. "Road planning and design information such as horizontal and vertical curvature and earthwork volumes are not readily apparent from maps but can be developed with the interactive 9830 calculator system and the road design program package. Road design alternatives can be evaluated at up to 1,000 feet of road per minute."

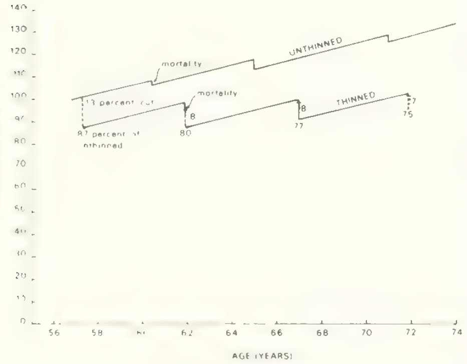
George Goddard, forest engineer on the Willamette National Forest in Eugene, Oregon, is impressed with the applications of the 9830 in stump-to-mill total systems planning. The Forest presently has units at Oakridge, McKenzie Bridge, and Sweet Home.

Personnel on the Willamette spent nearly a year debating the pros and cons of the various software systems presently on the market. Goddard talked with representatives from Hewlett-Packard and discussed the function and capabilities of various systems with the Seattle engineers. The result was a decision to go with the 9830.

According to Goddard, the system is a real benefit in putting sales on the Forest's 5-year action plan. "We can see if we have a go or no go situation, and we know right now whether we can put the sale in our plan or not. Later on, we can refine the system for specific sales that we decide to include. The 9830 enables us to examine a lot of alternatives in a very short time.

Yields With and Without Repeated Commercial Thinnings in a High-Site Quality Douglas-fir Stand, by Donald L. Reukema and Leon V. Pienaar (61)

A high-site-quality Douglas-fir stand was first thinned when about 57 years old and at 5-year intervals thereafter through approximately age 72. The thinnings evidently caused about a 10-percent reduction in gross growth per acre. On the other hand, 15-year diameter growth of surviving trees was 29 percent greater in thinned than in unthinned stands. The reduction in gross growth was more than offset by forestalling and salvaging mortality. As a result, if the final harvest is made 10 years after the last thinning, at about age 82, thinnings will have brought about an estimated 5-percent increase in total usable production. Removal of volume in these thinnings will have resulted in about a 20-percent reduction in volume to be cut at that final harvest.



Relative cubic volume growth and yield in thinned and unthinned stands.

Individual Trees Respond To Thinning

As more young Douglas-fir stands in the Pacific Northwest come under intensive management, it becomes increasingly important to develop better thinning techniques based on sound scientific principles. Two experiments were set up to measure the effect of different degrees of release on the growth of dominant, codominant, and intermediate trees. The initial test was in a 41-year-old natural Douglas-fir stand. A second test in a nearby 30-year-old plantation permits a comparison of early results.

In the 41-year-old stand, remeasurement at the end of four growing seasons showed that dominants respond more quickly and positively to the removal of competing trees than codominants or intermediates. A second remeasurement at the end of seven growing seasons substantiated this trend.

Three-year results in the 30-year-old plantation showed no significant effect of release on tree growth.

See *Response of Individual Douglas-fir Trees to Release,* by Donald L. Reukema (63) and *Diameter Growth of Plantation-Grown Douglas-fir Trees Under Varying Degrees of Release,* by Kenneth W. Krueger (64).

Production Rates in Commercial Thinning of Young-Growth Douglas-fir, by Thomas C. Adams (62)

This study has identified the variable factors that affect production rates of commercial thinning and provides a basis for estimating logging costs over a wide range of situations. Time studies were made of the individual steps in commercial thinning operations: felling, bucking, skidding, and loading. Equations were then developed that express time study results in terms of (a) log and tree volume in cubic and board feet, (b) several stand variables, and (c) alternative types of logging equipment.

Specific findings of the study were:

1. After the first thinning, some cost savings can be expected in subsequent thinnings.
2. Low volumes per turn or per log tend to give sharply increased unit costs.
3. Under favorable conditions, logs as small as 2.5 cubic feet or 10 board feet can be carried along with larger logs at no additional costs.
4. All logs other than bonus logs must bear the direct costs for the full amount of their handling from woods to mill.

Although the report was published in 1967, the basic data is still being used by the Bureau of Land Management (a cooperator in the study) to plan thinning operations. BLM has revised the logging cost estimates, but other data is still usable.

A 65-hp. tractor decks saw logs at edge of the landing.

Litter Fall in a Young Douglas-fir Stand As Influenced by Thinning, by Donald L. Reukema (65)

Litter falling to the forest floor plays a fundamental role in soil formation and fertility and has a basic influence on forest productivity. A study conducted in the Voight Creek Experimental Forest in western Washington has helped scientists learn more about the amount and timing of litter fall and how these factors are influenced by thinning. Research results are of considerable scientific interest and provide background data for studies of nutrient cycling in forest stands.

Average litter fall in the unthinned Douglas-fir stand was 1,974 pounds per acre per year. On the average, litter fall remained nearly proportional to basal area over the 13-year period of the study. Thus, thinning reduced the amount of litter fall.

Crown Expansion and Stem Radial Growth of Douglas-fir as Influenced by Release, by Donald L. Reukema (66)

A study in a 50-year-old Douglas-fir stand in western Washington indicated that release by thinning tends to reduce rather than accelerate crown expansion during the first few growing seasons following thinning. This effect was most pronounced in the upper part of the crown. Moreover, when released and unreleased sides of a given tree were compared, no differences in branch elongation were apparent. Stem radial growth was increased by release, progressively improving lower on the stem. Thus, apparently, crown buildup was not a major contributing factor in the stem-growth response of released trees.

Seed Production of Douglas-fir Increased by Thinning, by Donald L. Reukema (67)

In planning thinnings and final harvest cuttings for stands of young-growth Douglas-fir, foresters need reliable information on the capacity of young-growth stands to bear seed, on the periodicity of seed crops, and on the effects of thinning and other forest practices on seed production. One of the first studies designed to help provide this information was begun in 1950.

A 1961 research note from this study provides the following conclusions: (a) in a good seed year, thinned stands of young Douglas-fir produce much more than unthinned stands, (b) thinning does not affect the proportion of sound seed produced, and (c) thinning does not stimulate seed production in poor seed years.

ponderosa pine

Effects on Understory Vegetation

With better management practices, production from overstocked ponderosa pine stands in the Pacific Northwest can be significantly increased. Large-scale thinning programs are currently underway, primarily to increase timber production. But other benefits seem likely, for example, to increase grass forage for cattle or wildlife.

In this study in north-central Washington, pine thinning caused significant increases in understory vegetation. After eight growing seasons, total understory yield ranged from 75 pounds per acre on the unthinned plots to 417 pounds under 26-foot pine spacing. The increase comprised 51 percent grasses, 37 percent forbs, and 12 percent shrubs.

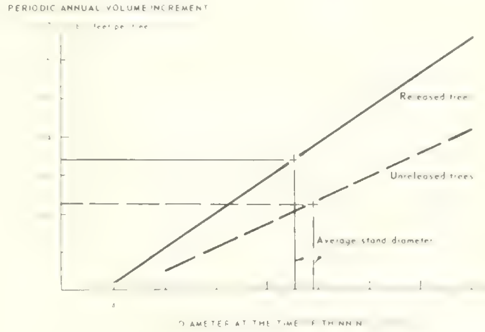
Details are found in *Response of Understory Vegetation to Ponderosa Pine Thinning in Eastern Washington,* by Burt R. McConnell and Justin G. Smith (68).

Only an occasional shrub and a few scattered grasses and forbs made up the understory before thinning (upper). Seven years after thinning to 18.7-foot spacing, 550 pounds of understory vegetation were being produced, including many desirable forage species (lower).

Dominant Ponderosa Pines Do Respond to Thinning, by James W. Barrett (69)

Over the years, considerable work has been done on thinning in ponderosa pine at the Pringle Falls Experimental Forest in central Oregon. An early study, begun in 1953, was designed to find out if dominant pole-sized ponderosa pine would respond to thinning. The answer, after 6 years of study, was a resounding "yes."

In this study, the leave trees responded by adding considerable girth—but no height. Researchers also noted that lower limbs on released trees did not die as much as in unreleased stands. Because dead limbs persist for many years on ponderosa pine, unreleased trees would have more loose knots than trees in the thinned stand. This could cause significant lumber degrade.

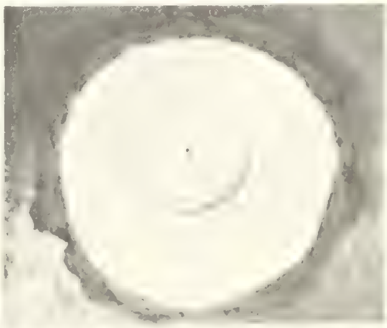


Average annual cubic-foot volume increment per dominant tree in relation to initial diameter.

Ponderosa Pine Saplings Respond to Control of Spacing and Understory Vegetation, by James W. Barrett (70)

Forest inventories indicate that about 5 million acres of commercial ponderosa pine forest land east of the Cascade Range in Washington and Oregon have a dense understory of suppressed trees. On many additional acres, the overstory has been removed, leaving dense thickets of 40- to 80-year-old, sapling-sized trees. Some managers have chosen to thin these residual stands while others, still hesitant about the investment in thinning, have elected to let the understory develop naturally. Most agree, however, that if these stands are to make reasonable progress toward producing a merchantable product, they must be thinned.

This paper presents 8-year-growth results from a spacing study in the Pringle Falls Experimental Forest, south of Bend, Oregon. This study was designed to give the manager a wide range of alternatives from which to choose an initial spacing.



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"The instant feedback of the 9830 approach has made our job of long-range planning an easier one. And, our road and logging designers are planning together in closer association than in the past. It's obvious that the design capabilities of systems such as the H-P 9830 will expand beyond the confines of skyline logging and road design."

end

OPERATION PHOENIX

by Thomas Michael Baugh

August 24, 1970, was hot and dry in north central Washington. On the Entiat Experimental Forest, near Wenatchee, U.S. Forest Service scientists scanned the skies with concern as the early morning light revealed a threatening buildup of thunderheads. Lightning bolts were soon lancing into the tinder-dry forest. Columns of smoke rose to meet the clouds as fire after fire began to rage across the bone-dry lands. By 8:00 p.m. of the same evening, it was all over for the Entiat Experimental Forest . . . or was it?

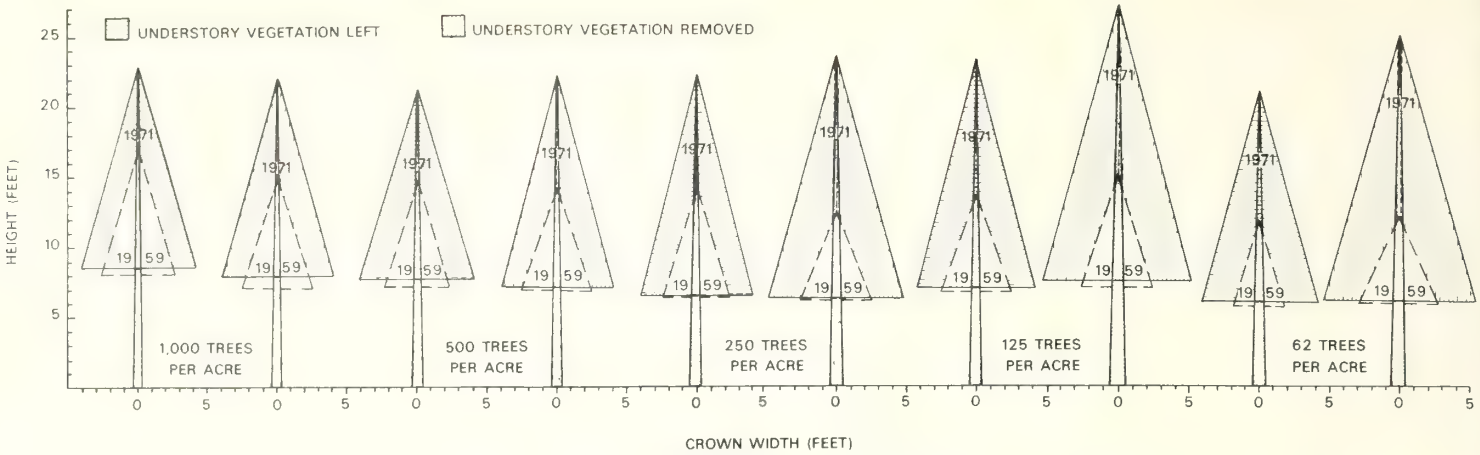
Scientists from the Forest Hydrology Laboratory in Wenatchee began studies in the Experimental Forest in 1959. They were investigating ways to improve water yield and water quality from the forest on the east side of the Cascades. Ten years of research had been invested when fire destroyed the Experimental Forest and thousands of surrounding acres.

The scientists were successful in saving much of their equipment as fire began to envelop the forest. Men with master's degrees and Ph.D.'s in soil science, hydrology, meteorology, and ecology became fire-fighters, joining hundreds of other men and women in an attempt to halt the massive blaze. The struggle was in vain, and as darkness fell it became apparent that the battle to save the Entiat had been lost.

The men who watched their outdoor laboratory disappear in grimy clouds of smoke were dedicated scientists. They could have thrown up their hands and walked away from what, at first, appeared to be the end of many years of research. But they didn't.

While dense smoke continued to blanket the community of Wenatchee, Project Leader Wally Berndt called his scientists together. Dr. Art Tiedemann, an ecologist, recalls Berndt's words. "We're going to be back in business on the Entiat," he said. "We're not going to abandon the Entiat."

* * *



Average crown dimensions of the 62 largest diameter trees per acre in 1959 and 12 growing seasons later. Crown widths for 1959 were estimated from 1971 regressions of crown width on diameter.

Thinning Increases Growth Rate

Thirty years of study of a natural ponderosa pine stand in the Pringle Falls Experimental Forest, south of Bend, Oregon, has taught foresters much about the desirability of thinning. At the time the study was begun, trees in the area were 40-70 years old and averaged an inch in diameter and 8.2 feet in height.

Researchers now believe that clearcutting and planting is **not** the best way to get this forest growing again. They recommend logging the old growth ponderosa pine carefully, thinning the understory saplings, and controlling the brushy understory. As much as 10 years of stand growth may be saved by controlling the brush, and additional time is saved by using the understory trees instead of planting.

In this study, saplings thinned 8 years earlier to 125 trees per acre grew three times the cubic wood volume that was being produced by the old growth before harvest. The sapling stand is now growing rapidly and may soon produce five to six times the wood of the overstory.

For details, see *Latest Results from the Pringle Falls Ponderosa Pine Spacing Study,* by James W. Barrett (71).

High Yields From 100-Year-Old Ponderosa Pine, by James W. Barrett and Richard P. Newman (72)

A 100-year-old stand of ponderosa pine on a good site responded with faster growth to a thinning from above which removed 20 percent of the volume. Growth in both thinned and unthinned stands of this age were impressive. But, because of attack by the mountain pine beetle, similar stands should be thinned lightly and frequently from below. In the last several years, mortality increased to about 77 percent more in the unthinned plots and was consistently lower in the thinned plots during the 30 years of observation.

Thinning Controls Pine Beetle

Dense stands of ponderosa pine are particularly vulnerable to attack by the mountain pine beetle. Research over the past 15 years indicates that thinning is probably the best prevention. But how much to thin and when? There is some question yet about that, but entomologists believe that thinning to the density required for normal silvicultural purposes will also prevent beetle attacks. Researchers figure, for example, that a stand density over 150 square feet per acre is hazardous for ponderosa pine at age 90.

Mountain Pine Beetle in Ponderosa Pine, by Charles Sartwell and Robert E. Stevens (73)

Jim Barrett

Thinning and Soil Moisture

Clues are provided here to the effects on moisture depletion and growth response after thinning in ponderosa pine. Age of the trees at time of thinning was about 50 years, with growth averaging only about .05 inch per year.

The response to thinning was good, with accelerated growth on trees that were left, and an additional bonus—reductions in moisture depletion in summer months. Since thinned stands in this region are widely scattered, there will not likely be increased water production in streams. But extra water is obviously available for growth of grasses and forbs.

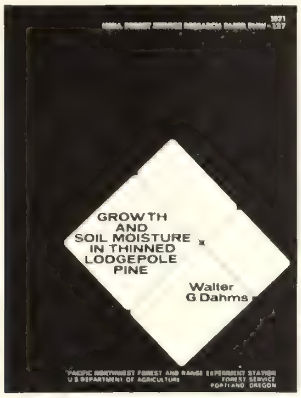
For details, see *Soil Moisture Depletion and Growth Rates After Thinning Ponderosa Pine,* by J.D. Helvey (74).

Large-Crowned Planted Ponderosa Pine Respond Well to Thinning, by James W. Barrett (75).

A 30-year-old planted stand of ponderosa pine responded well to thinning in central Oregon studies. A variety of levels of spacing produced similar increases in wood volume for the stand. Stands thinned to the widest spacing (17.6 feet) grew in diameter at an average rate of 2.7 inches per decade. Those at the narrowest spacing (8.8 feet) grew less than 1 inch per decade.

Most trees left after thinning were full-crowned and capable of responding to the additional growing space provided by thinning.

odgepole pine



GROWTH AND SOIL MOISTURE IN THINNED LODGEPOLE PINE

Walter G Dahms

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U S DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PORTLAND OREGON

Growth and Soil Moisture in Thinned Lodgepole Pine, by Walter G. Dahms (76)

The rewards from thinning lodgepole pine may be greater than for thinning most other species. Most natural stands are very dense and produce few merchantable trees. As a result, a major part of the total wood produced in these stands ends up as residue following logging.

The study was conducted in the Twin Lakes area of the Deschutes National Forest in Oregon. At the time of this report, three thinnings had been made: the initial one in 1959, and additional cuts in 1964 and 1969. Results indicate that foresters can capture most of the total wood production on usable-sized trees by controlling stand density. Furthermore, the density that is best for timber production also took less water from the soil.

See also another paper by Dahms on the same study, *Growth Response in Lodgepole Pine Following Precommercial Thinning* (77).

Fifty-Five-Year-Old Lodgepole Pine Responds to Thinning, by Walter G. Dahms (78)

A 55-year-old stand of lodgepole pine, after thinning in 1934, has shown considerable increase in wood volume. Barrett (1961) reported a good response of individual tree growth during the first 22 years. At the end of 32 years, net annual per acre volume increment on two thinned plots averaged 300 board feet. But the overall gain from the thinning was modest. The main problem is that the stand was heavily infected with rust diseases. An unpublished office report when the study began indicates that:

"During the establishment of these plots it was difficult to pick out the healthiest trees because of the presence of fungus diseases throughout the stand. . . . Almost all dead trees and those lacking in vigor were infected by one or both of these diseases. Although the healthiest trees were left, 67 percent of these were attacked."

At the end of 32 years, rust-caused mortality was still high, accounting for about three-fourths of the total volume loss. Although the amount of rust in this stand is higher than normally found in lodgepole pine, the wide distribution of cankers in this species indicates there would usually be losses.

Delay Thinning—Waste Wood

Putting off thinning until a stand of lodgepole pine was 47 years old meant considerable waste of site productivity. That conclusion comes from a study at Snow Creek in the Deschutes National Forest south of Bend, Oregon. Because of the delay, a large volume of wood was grown on trees that had almost no chance to reach usable size. As a result, there was very little response to thinning during the first 5 years after cutting. Researchers expect the trees will eventually resume their normal growth rate.

One reason to thin a stand of this age, however, would be to increase streamflow from the area. Soil moisture withdrawal was definitely less after thinning.

Tree Growth and Water Use Response to Thinning in a 47-Year-Old Lodgepole Pine Stand, by Walter G. Dahms (79).

Low Stand Density Speeds Lodgepole Pine Tree Growth, by Walter G. Dahms (80)

For the silviculturist, judicious control of tree density throughout the life of a forest stand is one of the best ways to optimize returns from timber growing. Tree density is especially critical in lodgepole pine because stagnation from overcrowding is probably more pronounced in this species than in any other western conifer.

The first of a series of experiments, designed to provide foresters with better basic information on growth-growing stock relationships in lodgepole pine (*Pinus contorta*), was started in a 22-year-old stand in central Oregon in 1959. This note reports findings from the first 5-year growth period.

"Operation Phoenix," named for the mythical bird which arose from its own ashes, was born during that meeting. Berndt asked each of his scientists to suggest ways of turning the disaster into a plus for forestry research. "We realized then that we had an unprecedented opportunity to study the effects of fire on the watershed," Tiedemann says.

Within several days the scientific staff at Wenatchee had redesigned their entire research program. Working closely with land managers from the Wenatchee National Forest, the scientists moved out into the still-smoldering stumps. They began to study the effects of wildfire and to evaluate ways of rehabilitating the watersheds.

Prior to the fire, the steep, rugged slopes of the Experimental Forest were covered with stands of Douglas-fir and other species of timber. The scientists had planned to harvest this timber in several different ways and to study the effects of logging on the watershed. Although the once green forests were gone, some blackened timber with salvage value remained. The research program was changed to include an intesive study of the environmental effects of salvage logging systems.

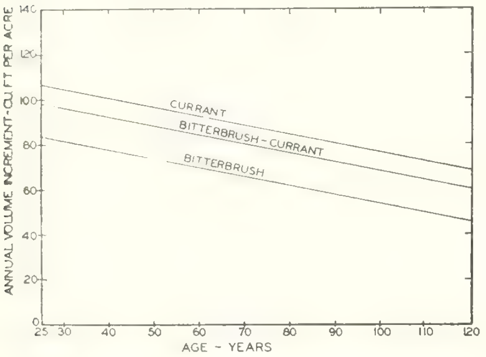
Large tractors began to haul scorched logs across the ash-covered slopes. In other areas, thick steel cables pulled salvageable timber down the hills to yarding areas. The effects of tractor logging on steep slopes were carefully monitored while log-carrying helicopters roared overhead removing dead trees. Scientists investigated a host of environmental factors during the timber salvage operations. The amount of stream sediment caused by each type of logging system was noted. The degree of damage to the slowly returning plant life and the disturbance to the soil were measured. The information concerning soil disturbance, stream sedimentation, and other factors is already being put to use by forest land managers who are responsible for similar fire-destroyed areas.

Throughout history, foresters have faced the problem of stabilizing land which has been burned by fire. Trees, plants, and grasses hold soil in place and allow water to seep into the earth at naturally controlled rates. Scientists worked with foresters from the Wenatchee National Forest to see what they could do to hold the thin soil on the mountain slopes. The four watersheds on the Entiat Experimental Forest were divided into four separate research zones. Each zone received a different type of experimental treatment.

Productivity Indices for Lodgepole Pine on Pumice Soils, by C.T. Youngberg and W.G. Dahms (81)

In central Oregon, productivity of lodgepole pine cannot be determined by soil series only. Categorizing stands on the basis of the understory plant communities present is a better indicator of productivity.

Although the information given is for lodgepole pine, it may also apply to ponderosa pine when growth is not restricted by poor drainage or low temperature.



Regression of lodgepole pine volume increment on age by plant community

western larch

Larch Grows Faster After Thinning

Western larch at 33 years of age responds well to thinning, a 5-year study indicates. Using the information presented, foresters can estimate the number and size of trees to leave in order to get desired future growth.

For example, in order to have all trees reach a diameter of 10 inches 20 years after the first thinning, the average stand diameter would have to be about 12 inches. In the example given, this would require leaving about 120 trees per acre at an average spacing of about 19 feet. This is based on the following assumptions:

1. The first thinning is a precommercial thinning designed to get enough growth on remaining stems that a commercial thinning can follow.
2. The second thinning is made 20 years later and removes only merchantable trees.
3. Basal area increment will continue at about the present rate during the 20-year period.
4. Little mortality will occur during the 20 years.

See *Growth of Young Even Aged Western Larch Stands After Thinning in Eastern Oregon*, by K.W. Seidel (82).

Ken Seidel

More on Western Larch

Thinning larch at age 33 may get the desired results, but don't count on it at age 55. By then, the trees are past the sapling and pole stage and cannot adjust to the new space available to them. Recommendations from this source are to thin when the trees are much younger.

Of course, if you're stuck with a 55-year-old stand and can't go back to 33, thinning from below may be worthwhile. For details, see *Response of Western Larch to Changes in Stand Density and Structure*, by K.W. Seidel (83).

fertilization

Douglas-fir Growth Can Be Increased Report From Pacific Northwest Shows, by Robert F. Strand and Richard E. Miller (84)

A nice summary, in not too technical terms, of what is currently known about forest fertilization in the Pacific Northwest:

1. Nitrogen fertilizer can increase growth of Douglas-fir on a wide range of stand age, stocking levels, and site quality.

2. Other elements have not been adequately tested to evaluate their importance.

3. In general, cubic-volume responses by Douglas-fir to nitrogen range from 0 to over 100 percent and probably average about 30 percent during a 5- to 7-year period.

4. Optimum rates of N appear to lie between 150 and 300 pounds per acre for a response duration of 5-7 years.

5. Existing fertilizer trials are potential sources of information about growth and yield in managed stands. They are local examples to help managers select stands for treatment.

Forest Fertilization: Foliar Application of Nitrogen Solutions Proves Efficient, by Richard E. Miller and Donald C. Young (85)

This article briefly discusses forest fertilization in the Pacific Northwest and southeastern United States and summarizes experiments comparing foliar applications of concentrated nitrogen solutions to Douglas-fir trees with conventional applications of urea prill to the soil. The purpose of foliar applications is direct entry of the fertilizer into the plant and avoiding the inevitable losses and fixations that occur when fertilizer is applied to the soil. The authors compare the costs of and growth response from these two methods of fertilization and conclude that with careful formulation and application to control the degree of foliar damage, foliar application of concentrated nitrogen solutions can be an efficient alternative to urea prill.

Nutrient Cycling in the Douglas-fir Type—Silvicultural Implications, by Richard E. Miller, Denis P. Lavender, and Charles C. Grier (86)

The authors describe nutrient cycling in Douglas-fir and show how various silvicultural treatments can affect stand nutrition by removing or adding nutrients or by altering the rate of a critical process in the nutrient cycle, such as organic matter decomposition. Adequate cycling of nitrogen is important to the growth of Northwest forests because N is normally the critical nutrient limiting growth. Through silvicultural practices, the land manager can affect forest nutrition and growth.

Dick Miller

growth responses

Fertilizing 75-Year-Old Trees

Seventy-five-year-old Douglas-fir trees responded well to fertilization, with increased growth during the 5 years after treatment with nitrogen in six different forms.

Basal area growth increased from 17 to 53 percent over unfertilized trees, but only ammonium nitrate at 300-N dosage increased growth enough to be statistically significant.

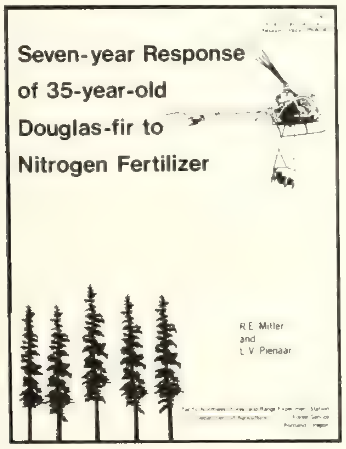
See *Seventy-Five-Year-Old Douglas-fir on High-Quality Site Respond to Nitrogen Fertilizer*, by Richard E. Miller and Donald L. Reukema (87).

Fertilizing and Thinning in Southwest Oregon

Growth of 30-year-old Douglas-fir trees on Site IV in southwest Oregon was increased by both thinning and fertilization. Four years after treatment, fertilization increased diameter growth of dominant trees by 57 percent on a clay loam and 28 percent on sandy loam soil. By fertilizing and thinning together, growth was increased by 94 and 132 percent respectively on the two soils. Height growth was not affected.

Researchers emphasized that only 4 years of observation had been summarized when these results were reported. It is likely that benefits will continue from both treatments.

Details are found in *Dominant Douglas-fir Respond to Fertilizing and Thinning in Southwest Oregon,* by Richard E. Miller and Richard L. Williamson (88).



Seven-year Response of 35-year-old Douglas-fir to Nitrogen Fertilizer

R.E. Miller and L.V. Pienaar

Seven-Year Response of 35-Year-Old Douglas-fir to Nitrogen Fertilizer, by R.E. Miller and L.V. Pienaar (89)

This paper describes the results of 7 years of observations following fertilization in a 35-year-old Douglas-fir plantation in the Wind River Experimental Forest in southwestern Washington. In an initial report, Reukema reported substantial increases in height, diameter, and basal area growth during the first 4 years after fertilization. These growth increases were sustained after 7 years and will likely continue in the future.

Ammonium nitrate was applied at rates of 140, 280, and 420 pounds N per acre. As a result, volume growth increased by 55, 92, and 109 percent, respectively. The increase at 140 pounds per acre was equivalent to temporarily raising the site quality by one class. With nitrogen at 280 and 420 pounds per acre, winter breakage of trees was increased, but not enough to outweigh the benefits from fertilization. So far, net gain in total cubic volume was as much as 83 percent, with the maximum gain from the 280-pound treatment.

Fertilize Western Hemlock—Yes or No? by Dean S. DeBell (90)

Growth response of hemlock to urea fertilizer has been highly inconsistent, varying from −20 percent (apparent growth depression) to +47 percent of annual basal area growth. Chances for obtaining a good response increase with latitude along the coastal belt and are better in the Cascades than on the coast. Stands that have been thinned or are naturally less dense respond better than dense, unthinned stands. Forest managers may get a profitable response to fertilization of hemlock in the Cascades and in British Columbia with present methods. However, successful fertilization of coastal hemlock must await the completion of research suggested in this paper.

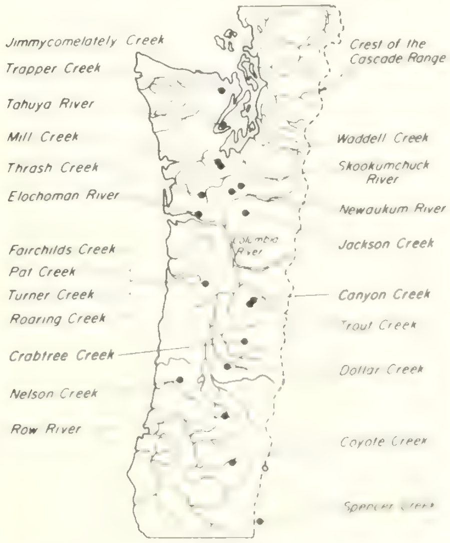
Fertilization and Water Quality

The effects of forest fertilization on water quality is being studied at 22 sites in western Oregon and Washington. In addition, other studies have been conducted in western Washington, Idaho, and southeast Alaska.

Following fertilization, increased levels of nitrogen have been detected in streams, not enough to have a measurable impact on eutrophication in downstream impoundments. Concentrations of the compounds have not approached levels considered unacceptable in public water supplies.

The amount of nitrogen entering streams can be kept at a minimum by leaving adequate buffer strips along main streams and larger tributaries. Also, fertilizer should not be applied when the streams are swollen by spring snowmelt or heavy storm activity.

See the technical report, *Impact of Forest Fertilization on Water Quality in the Douglas-fir Region—A Summary of Monitoring Studies,* by Duane G. Moore (91).



Location of forest fertilization water quality monitoring studies in western Oregon and Washington.

The easternmost watershed was left untouched, no seed or fertilizer was applied, and no roads were built. The scientists used it to study the ways in which nature, unaided by man, reacted to wildfire. They noticed, among many other things, that snowbrush ceanothus, a natural ground cover, began to reestablish itself within 1 month after the fire. The seeds of this shrub are known to lie dormant for hundreds of years and only germinate after being exposed to fire.

McCree Creek which lies near the center of the Experimental Forest was treated with a urea fertilizer high in nitrogen content. Ammonium sulfate, also high in nitrogen, was applied to adjacent Burns Creek. The fourth watershed, Brennegan Creek to the west, was not fertilized.

Using fixed-wing aircraft and helicopters, the scientists then seeded the McCree, Burns, and Brennegan watersheds with a variety of different plants. Orchardgrass, hard fescue, Drummond timothy, perennial ryegrass, and yellow sweet clover were applied uniformly across these three watersheds.

Soil stability and land stabilization are not the only problems experienced by land managers following a fire. Many of the nutrients found in the plant and litter materials on top of the ground are burned and converted to oxides which are mixed with the ashes. These nutrients are lost when rain water and snowmelt leaches them from the soil into the streams. The loss of nutrients can make the land less productive and pollute the water in the streams.

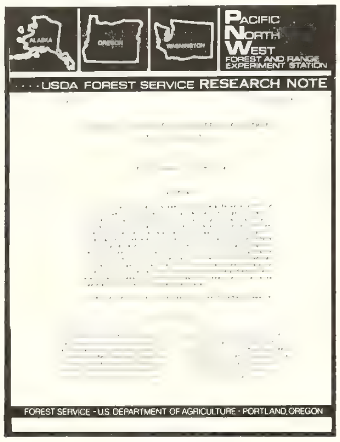
Immediately following the fire the scientists began to measure and record the nutrient and soil loss which was occurring on the untreated watershed. Over the years they have been able to compare this data with the information obtained from the other three areas where various rehabilitation activities took place.

In general they found that the locations treated with both fertilizer and seed had higher plant productivity, less erosion, and higher stream nutrient levels. Erosion was heavy on the untreated watershed, and the stream filled with silt, washing large amounts of nutrients from the soil. The ground cover on Brennegan Creek was similar to that on the seeded and fertilized watersheds, but plant productivity and health was lower. The scientists found that orchardgrass and

Fertilizing Lodgepole Pine

The price of fertilizer has a definite effect on its use for improving the growth of low-producing stands of lodgepole pine. As a result, it is important to be able to quantify the growth increases that might result from fertilization. Initial research results (one study) indicate that heavy doses of nitrogen, phosphorous, and sulphur can greatly increase diameter growth—at least for 4 years, and probably beyond that. In addition, fertilization increased grass production in the understory.

Fertilization was heavy: 600 pounds per acre of nitrogen, 300 pounds of phosphorous, and 90 pounds of sulphur. Read more in *Response of Pole-Size Lodgepole Pine to Fertilization,* by P.H. Cochran (92).



PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

FOREST SERVICE · U.S. DEPARTMENT OF AGRICULTURE · PORTLAND, OREGON

Fertilizing Ponderosa Pine

Initial studies in four areas indicate promising results with a combined treatment of fertilizing and thinning in ponderosa pine.

This study was carried out in ponderosa pine that was 40 to 65 years old in 1967. The stand was first thinned, then nitrogen fertilizer was applied alone or in combination with P, S, and B to the soil around some of the remaining trees. As a result, diameter growth increased substantially. Height growth also increased, except where research results were confused by insect-caused top damage. Volume growth was significantly increased by fertilization in all but one location—an especially dry site near Fort Rock in central Oregon.

It should be noted that these growth increases were in connection with thinning, a proven tool for producing more usable wood. Considerable research is necessary before guidelines can be recommended for fertilizing only. This work is underway.

For details of the study, see *Response of Individual Ponderosa Pine Trees to Fertilization,* by P.H. Cochran (93).

Forest Fertilization in the Pacific Northwest—A Case Study in Timber Production Under Uncertainty, by Dennis L. Schweitzer (94)

The future of forest fertilization is plagued with uncertainties—lack of knowledge of the physical response to forest fertilization, lack of good ways to determine which stands will benefit most from fertilization, application technology, and the environmental and political climate.

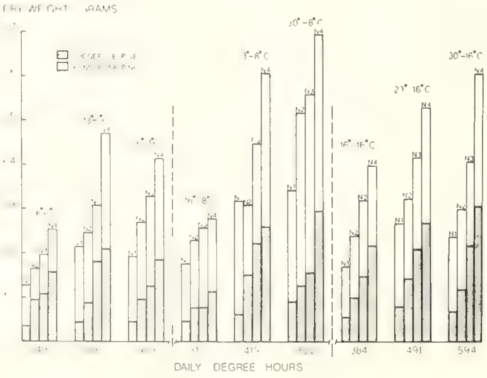
All of these uncertainties result in a lack of complete information for the forest resource manager. For the present, in the Pacific Northwest, fertilization will continue to be justified on the basis of the fragmentary experimental and experience data that are available and by the advantages gained through the allowable cut effect.

Temperature and Soil Fertility Affect Lodgepole and Ponderosa Pine Seedling Growth, by P.H. Cochran (95)

Do species differences exist between ponderosa and lodgepole pine in their response to temperature and soil fertility? A study was undertaken to find the answer to this question, with seeds taken from the Pringle Falls Experimental Forest and planted in growth chambers. There, light intensity and day and night temperatures were carefully controlled, and the soil fertilized with various levels of nitrogen.

Results of the study did not explain the growth differences sometimes found between lodgepole and ponderosa pine in south central Oregon, but an interesting relationship surfaced. It appeared that as more nitrogen was added to the soil, warmer night temperatures were required to produce maximum growth rates. In future studies of the effect of temperature on seedling growth, researchers should pay more attention to the soil fertility.

Studies such as this, carried out under controlled laboratory conditions, are also useful as a first indicator of whether various tree species will benefit from forest fertilization.



Dry weights of lodgepole and ponderosa pine seedlings grown under four increasing levels of soil fertility and nine temperature regimes.

Fertilizing Planted Ponderosa Pine on Pumice Soils, by J.W. Barrett (96)

Foresters should be aware that exciting possibilities exist for stimulating growth of planted ponderosa pine with fertilizers. But research suggests caution until more positive results are obtained.

Author Barrett reports information from several tests using different types of fertilizers. None of the fertilizers used met all the objectives—that is, a fertilizer that will shorten the time to timber harvest, enable the tree to maintain reasonable growth, survive in the midst of competing vegetation, and increase in size quickly and be unattractive to browsing animals.

environmental effects

Monitoring Water Quality

Forest fertilization on a commercial scale began in the Pacific Northwest in 1965. Under pressures of increasing demands for wood fiber, this management practice has grown rapidly. Between 1965 and 1969, approximately 36,400 hectares were fertilized in western Oregon and Washington. By 1974 this figure increased to over 285,000 hectares.

Although the total acreage fertilized is relatively small and widely scattered, it is important to know how much nitrogen is getting into streams and what its environmental effect will be. Consequently, monitoring studies were established in Oregon, Washington, and Alaska to measure nitrogen in streams under a variety of conditions of soil, climate, and vegetative species.

Results so far indicate that the amount of nitrogen that enters streams from fertilization is relatively small and should not have a measurable impact on eutrophication. Nitrogen levels can be kept at a minimum by providing buffer strips along streams and larger tributaries. In addition, fertilizer should not be applied to watersheds during spring snowmelt or heavy storms.

For an interesting summary, see *Impact of Forest Fertilization on Water Quality in the Douglas-fir Region—A Summary of Monitoring Studies,* by Duane G. Moore (97). See also a paper by Moore titled, *Fertilization and Water Quality,* (98).

Duane Moore

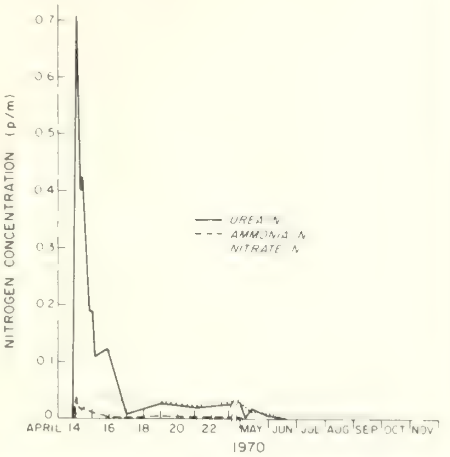
Effects of Forest Fertilization With Urea on Stream Water Quality—Quilcene Ranger District, Washington, by Duane G. Moore (99)

Application of nitrogen fertilizer to two units of the Quilcene Ranger District of the Olympic National Forest in April 1970 provided an opportunity to monitor water quality in small streams adjacent to the treated areas.

Application rate was low—224 kilograms nitrogen per hectare (200 pounds nitrogen per acre). Detectable amounts of nitrogen were found in streams after aerial application, but concentrations were very small.

It seems apparent that the small amounts of nitrogen applied in this area would have little measurable impact on eutrophication.

For other studies on the effects of fertilization on water quality, see results of research in the Entiat Experimental Forest near Wenatchee, Washington. Considerable work has been done there on fertilization of grasses following wildfire. See sections on watershed management and chemicals in the environment.



Concentrations of urea, ammonia, and nitrate nitrogen in streamflow following fertilization of a 49-hectare unit with 224 kilograms urea-N/ha in April 1970—Jimmycomelately Creek, Quilcene Ranger District, Olympic National Forest, Washington

role of red alder

We include a special section here on the role of red alder, a beautiful, but sometimes misunderstood hardwood. Alder grows along streambanks and in cutover areas and along old skid roads. As its lacy lime-green leaves unfold, it is a first welcome sign of spring throughout much of the West.

But during recent decades, forest management has become increasingly intensive in this region. In striving for higher yields of more valuable trees such as Douglas-fir, forest managers have tended to regard alder as a weed species. Research, however, continues to point out its desirable properties.

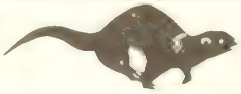
Scientists, including silviculturists, plant pathologists, and microbiologists have been fascinated by the red alder. For one scientist—Robert F. Tarrant—his research has meant international acclaim. In part for his research to identify the role of red alder in fixing nitrogen in the soil, Tarrant was awarded the USDA Superior Service Award in 1973.

There are no practical guidelines published on how to use red alder to improve the nitrogen balance in forest soils, or to control diseases such as *Phellinus weirii* (*Poria*). But there are strong suggestions that this may be possible in the future. Additional research, or field trials, may provide the answers.

Biology of Alder, edited by J.M. Trappe, J.F. Franklin, R.F. Tarrant, and G.M. Hansen (100)

The beneficial role of red alder in the Douglas fir forest has long been recognized. Alder is a nitrogen-fixing plant, meaning its roots have nodules that "capture" nitrogen from the air and transform it into nitrogenous compounds that plants can absorb from the soil. The appearance of this leafy hardwood in forest ecosystems following fire, or on old logging roads or disturbed sites, may be especially significant. In this role, alder may help prepare the soil for later growth of conifers such as Douglas-fir.

This publication is a summary of reports given at the 40th annual meeting of the Northwest Scientific Association in Pullman, Washington, April 14-15, 1967. Many are quite technical and of background rather than immediate practical use. But the publication will help foresters appreciate an important tree that was once considered a "weed species."



hard fescue produced the best results of any of the seeds which were tried. As the grasses took hold, the amount of water loss also decreased.

The effects of the urea and ammonium sulfate fertilizers have also been carefully monitored throughout the research effort. Tiedemann points out that it would be of little help to land managers to be able to establish plant cover on steep slopes if the streams were polluted by fertilizer. Small amounts of the fertilizers did find their way into both Burns and McCree Creeks. The tests used showed that the amounts were so small that they had no significant effect on stream life or water quality.

Changes in water yield were perhaps the most dramatic effects noted on the Entiat. Researchers found that the amount of water flowing from the denuded slopes almost doubled during the first year following the fire. Heavy precipitation during the second year caused an increase in water yield four to five times above normal.

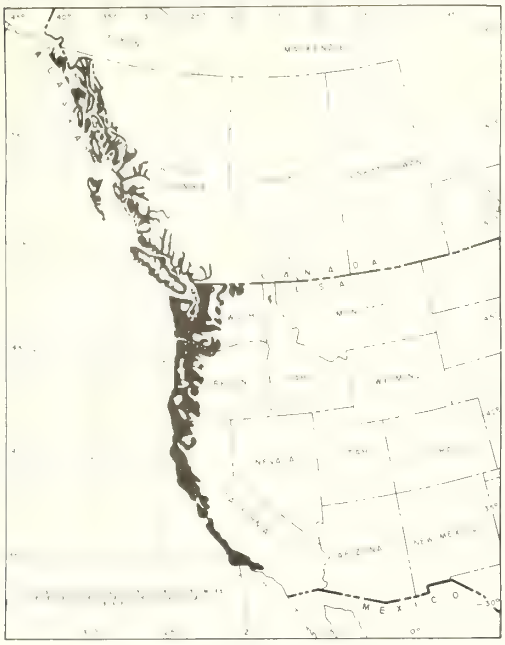
The outcome of the research on the Entiat Experimental Forest has helped to provide guidelines for land managers who will continue to be faced with wildfire and other erosion problems. Each year foresters from federal and private companies visit the Forest Hydrology Laboratory and the Experimental Forest. They come to discuss their problems with the scientists and to learn what can be done to rebuild similar burned watersheds in other parts of the country.

end

A VIRUS THAT KILLS THE TUSSOCK MOTH

by Louise Parker

The year 1973 might well be called "The Year of the Tussock Moth." But for Dr. Hank Thompson, concern about the tussock moth began back in 1964, 4 years after he joined the Forestry Sciences Laboratory in Corvallis, Oregon, as a research entomologist with the Forest Service. That was about the time people were becoming concerned about the effects of pesticides and other chemicals on the environment. DDT was going out of favor, and foresters were anxious to find some new control methods—techniques that would be safer for use around fish and other wildlife. Natural biological controls looked promising because most insects have diseases and are subject to attack by parasites and predators. Thompson's assignment was to set up a new research project to explore the use of natural biological controls to halt the spread of forest insect outbreaks.



Range of red alder

Red Alder: Its Management and Utilization, by Norman P. Worthington, Robert H. Ruth, and Elmer E. Matson (101)

Getting a little old now, this 44-page report still contains a lot of useful information about the red alder—its range and distribution, characteristics, wood properties, major uses, etc. The information that's really old (primarily wood production data) has been updated in a new publication, titled simply *Alder,* an American woods leaflet (FS-215) by Marlin E. Plank, November 1971 (102).

Red alder is used today primarily for pulpwood, with lumber for furniture next in importance. Production has gone up dramatically in this century. Production of red alder lumber was first reported in 1907 as 115,000 board feet. That increased rapidly in the late 1920's, and in 1965 production was estimated at 82 million board feet. Use of alder for pulpwood has grown rapidly since the early 1950's.

Stand Development and Soil Fertility in a Douglas-fir Red Alder Plantation, by R.F. Tarrant (103)

The story of research on red alder is one that again demonstrates just how long it takes between the development of new knowledge and its practical application in the forest. Not that that's all bad. In many cases, it takes a long time to verify research findings and develop practical applications.

For example, scientists have known since the early 19th century that alder has root nodules. Later studies indicated that the nodules resemble those of legumes in that they are nitrogen-fixing. In 1951, PNW forest scientists learned that red alder foliage contains much greater amounts of nitrogen than other tree species in the Pacific Northwest (104).

Another 10 years passed before an article in *Forest Science* by Robert F. Tarrant thoroughly established this concept in the Pacific Northwest (101). Tarrant studied stands of Douglas-fir and Douglas-fir mixed with alder in experimental plantings in the Wind River Experimental Forest near Carson, Washington. Tarrant found that the addition of red alder to the site enabled a 27-year-old mixed stand of Douglas-fir and red alder to produce more than twice the wood volume of a similar site with Douglas-fir only! Even though there were more Douglas-fir stems in the pure plantation, in the mixed stand there were an average of 443 stems per acre—enough for satisfactory stocking. Moreover, there were an additional 627 red alder trees! Tarrant realized that it was the addition of increased amounts of nitrogen to the soil that enabled this phenomenal wood production.

In addition, the Douglas-firs growing with alder were larger and better formed than those that grew alone. The partnership of Douglas-fir and red alder had proven to be a healthy one.

So, should foresters go out and plant red alder with Douglas-fir to produce greater yields everywhere? Not necessarily, says silviculturist Richard E. Miller. Miller, who did a follow-up study with Tarrant in the same forest stands (105), cautions that the Wind River studies were done under conditions that would show a maximum benefit from red alder. For example, the alder was planted after the Douglas-fir and did not compete with the fir as on many high sites in the Douglas-fir region. There, alder normally suppresses Douglas-fir if it gets a head start.

Scientists at Oregon State University have also done some studies with red alder. Their results suggest that alder might be planted in heavily thinned stands of Douglas-fir to increase production of the fir. Ten years after thinning, the alder understory was deteriorating, and many of the alder trees were dead. In the meantime, however, the alder had contributed hundreds of pounds of nitrogen to the soil and litter on the forest floor. For details of that study, see *Natural Fertilization of a Heavily Thinned Douglas-fir Stand by Understory Red Alder,* School of Forestry, OSU, Forest Research Laboratory, Research Note No. 56, 1975, by Alan Berg and Allan Doerksen.

Accumulation of Organic Matter and Soil Nitrogen Beneath a Plantation of Douglas-fir and Red Alder, by R.F. Tarrant and Richard E. Miller (105)

Another report from the same study describes the actual amount of nitrogen added to the soil by the alder. Tarrant and Miller dug holes in the ground to get soil samples, down to just below root level. They found greater quantities of nitrogen in the mixed stand down to a depth of 36 inches.

Over the 30-year period of growth of the stands, the scientists calculated that total nitrogen in the soils and forest floor averaged about 3,000 pounds per acre in the Douglas-fir forest. In the mixed stand, it was about 4,000 pounds per acre. This meant that about 1,000 pounds of nitrogen had been added to the soil by the red alder trees during the 30 years. On a yearly basis, that figured out to about 36 pounds of nitrogen per acre per year—added because of the alder trees.

Coastal Study Confirms Data

Later research in the Cascade Head Experimental Forest on the central Oregon coast verified the general trend of the findings at Wind River, but indicated a three-fold increase in the amount of nitrogen circulating in the ecosystem from the addition of red alder.

In that study, scientists measured litter fall under three types of stands: (a) red alder only, (b) red alder and conifers mixed, and (c) conifers only (Douglas-fir, western hemlock, and Sitka spruce). The scientists measured only 32 pounds of nitrogen per acre in litter under the conifer stand. But the alder stand contained 100 pounds per acre and the mixed site 104 pounds per acre.

See Tarrant, Lu, Bollen, and Franklin's, *Nitrogen Enrichment of Two Forest Ecosystems by Red Alder* (106).

Nitrogen Addition by Stemflow

In another study at Cascade Head, scientists also investigated the role of rainfall in adding nitrogen to soils in the alder stand. They collected both stemflow (water draining down tree trunks) and rainwater that had dripped through alder foliage. Results indicate that the amount of nitrogen added in this way is minimal. Litter fall is a much more significant source of nitrogen.

See *Nutrient Cycling by Throughfall and Stemflow Precipitation in Three Coastal Oregon Forest Types,* by Tarrant, Lu, Bollen, and Chen (107).

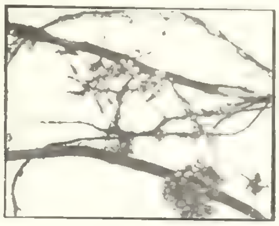
Red Alder and *Poria weirii*

Since first identifying the capacity of red alder to add nitrogen to the soil, scientists have continued to explore several possibilities: (a) increasing forest productivity with red alder, and (b) the possibility that it may be useful in controlling or preventing root diseases of conifers.

Several technical reports have been published. For a nice summary of the possible role of red alder in preventing the root disease *Poria weirii* (now *Phellinus weirii*), see an article by James M. Trappe, *Regulation of Soil Organisms by Red Alder: A Potential Biological System for Control of Poria weirii,* from a symposium at Oregon State University in 1970 (108).

Trappe points out that the addition of nitrogen to forest soils may help reduce the viability of buried *Poria*. Red alder also produces large amounts of other compounds that are known to be *Poria* inhibiting—for example, phenolics and fatty acids. In addition, the microorganisms that form nitrogen-fixing nodules on red alder roots are in an order which includes antibiotic producers. These may be useful in inhibiting *Poria*.

Furthermore, red alder is known to resist attack by *P. weirii.* For these reasons, the long term alteration of sites may be the best hope of controlling the disease in the future. Trappe speculates further that: "Much of the buried *Poria* in clearcuttings (from stumps of infected trees that were cut) likely would be starved out if a rotation of alder were grown for several decades."



Nitrogen fixing nodules on red alder root.

Other reports on this subject are quite technical. Check the bibliography for a complete listing (109).

Subsequent research on the role of red alder in inhibiting *Poria weirii* has not yet met with success. Earl Nelson did a study (see 109) where little cubes of wood inoculated with *Poria* were buried for several years in a red alder stand. The *Poria* was not killed.

A later study by Everett Hansen (110) was done to see if *Poria* was inhibited in a Douglas-fir plantation with intermixed red alder. It wasn't, at least not yet, and trees were then about 10-17 years old. But it might work better if alder were established for a couple of years before the Douglas-fir was introduced.

Results of both studies are inconclusive. Long-term research may help answer the question.

The Role of *Alnus* in Improving the Forest Environment, by Tarrant and Trappe (111)

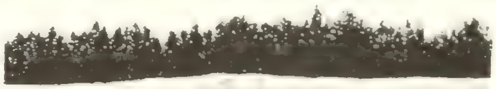
This 13-page article is an excellent summary of what is known about the role of red alder and its beneficial effects on forest environments in the Pacific Northwest.

Growth and Development of Red Alder Compared With Conifers in 30-Year-Old Stands, by Carl M. Berntsen (112)

In 1935, a long-term study was begun to learn more about growth and development of red alder compared to conifer stands. Several treatments were made to get stands that were pure alder or conifer, with various combinations of thinned and unthinned.

Results indicate that the conifer stand responded to thinning. In contrast, the pure alder stand showed only negligible accelerated growth. Lack of thinning in the alder conifer stand, however, resulted in a prolonged struggle between species that reduced yield.

One of Thompson's first concerns was to narrow the problem. "Everyone tries to do too much," he says. "That just dilutes the effort and you can't solve any one problem." Since the mid-1960's, almost all of his work has been on the tussock moth and the viruses and other disease agents which attack it. Most of the research has been on study of a nucleopolyhedrosis virus which helps control the tussock moth outbreaks in nature.



One of the difficulties with entomological research is the cyclic nature of insect outbreaks. "They'll be up for a few years, then down," Thompson says. "When they're down you can't even find a tussock moth in the woods."

In 1964, outbreaks appeared in several parts of the West, giving scientists an opportunity to work on the tussock moth. In the succeeding years, Thompson's research team of four scientists and four technicians has made considerable progress in developing a sound biological control for the tussock moth. They have:

- *Developed techniques to raise tussock moths in the laboratory for experimental purposes. Thousands of moths have been reared on artificial diets and used in the research.*
- *Identified the natural microbial enemies (viruses and bacteria) which attack the tussock moth at various stages of development.*

role of mycorrhizae

Mycorrhiza literally means "fungus-root". It is a structure that combines the plant root and the fungus. Mycorrhizae have fascinated scientists for years, and with good reason. The symbiotic, or mutually beneficial, relationships which bind fungi and plants together, are a biological continuation from earliest times. As plants evolved in primeval waters, both algae and fungi were present. Probably neither could subsist alone on land. But together they could survive, the algae a specialist in producing chlorophyll, and the fungi scavenging mineral nutrients from the soil.

Today, the mycorrhizal fungi and roots still coexist, each doing its own important work. Without these beneficial fungi, most modern plants, including forest trees, could not survive.

Occurrence of Mycorrhizae After Logging and Slash Burning in the Douglas-fir Forest Type, by Ernest Wright and Robert F. Tarrant (113)

There are two principal types of mycorrhizae: endotrophic—with the fungus inside the root cells; and ectotrophic—with an external fungal mantle enveloping the root tips and the fungus between outer root cells, but not in them. Both types are most abundant in the upper part of the soil. The ectotrophic ones are more common on trees of the Douglas-fir region.

To check the effect of slash burning on mycorrhizae of Douglas-fir, researchers examined roots of seedlings 1 and 2 years after logging in the Wind River and H.J. Andrews Experimental Forests.

In study areas, the seedlings had more mycorrhizae after 2 years than after 1 year. Unburned sites had more mycorrhizal seedlings than burned sites. At Wind River, mycorrhizae were more common on lightly burned sites than severely burned sites, but this difference did not show up on the Andrews.

Jim Trappe

Fungus Associates of Ectotrophic Mycorrhizae, by James M. Trappe (114)

Plant pathologist Jim Trappe is especially proud of this publication. It's primarily written for specialists, but has served as a basic reference for much of the subsequent mycorrhiza research.

Here is a listing of all the fungi known up to 1962 to produce ectotrophic mycorrhizae on specific tree hosts (see the last article if you haven't already). Among these, nature lovers and botanists will recognize many of the common forest mushrooms—boletus and the deadly amanita for example.

Trappe says it is extremely important to identify and classify the fungi as a first step in working with them. There is a great physiological diversity in the fungi. Each has a different function in the life of the forest. One may protect roots against disease. Another may help the tree survive on dry sites.

In the past 10 years, dozens of papers have pointed out differences in these fungi. As these become known, scientists will be able to determine which are most helpful in promoting establishment, growth, and health of tree seedlings.

Mycorrhizal Deficiency in a Douglas-fir Region Nursery, by James M. Trappe and Robert F. Strand (115)

Nurserymen should be especially careful when fumigating soils in forest tree nurseries. Fumigation can kill important mycorrhizal fungi as well as disease-producing ones!

Seedlings in a forest nursery in the Willamette Valley in Oregon were severely stunted, sickly, and would not respond to fertilizer. On close examination, plant pathologists found that the trees were nonmycorrhizal. Ectomycorrhizal fungi were apparently sparse in the soil because of soil fumigation during development of the nursery.

The problem is that Douglas-fir needs phosphorous and micronutrients that they can't absorb by themselves. They need the mycorrhizal fungi, which pick up phosphorous from the soil and pass it on to the trees.

Because of research such as this, nurserymen now know that if they fumigate the soil to kill the harmful diseases, the beneficial mycorrhizal fungi must then be replaced.

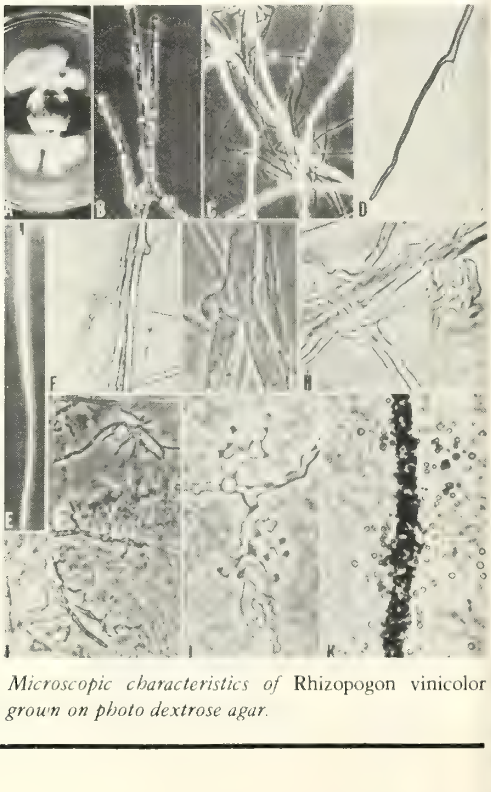
Mycorrhizae and Container Seedlings, by B. Zak (116)

Mycorrhizae were discovered nearly a century ago; trees have been known to depend on mycorrhizal fungi for uptake of nutrients from soil for well over 50 years. Only recently, however, has it become possible to manipulate mycorrhizal fungi to increase survival and growth of planted seedlings. Now fungi can be selected for particular qualities; for example, drought resistance or production of growth regulators to speed root growth of hosts or strong antagonism against root diseases. These fungi can be inoculated on seedlings grown in nursery beds or containers. Containerized seedlings offer particularly good opportunities because the fungal inoculum can be incorporated directly into the container mix just before seeding. The technology of large scale inoculation is now being developed. In a few years, it may well be possible to "tailor" mycorrhizae for the sites for which the seedlings are destined.

Characterization and Classification of Mycorrhizae of Douglas-fir. II. *Pseudotsuga menziesii* + *Rhizopogon vinicolor*, by B. Zak (117)

Hi. Are you still with us? This paper will defy the average reader, but we talked with a plant pathologist to learn just what it's all about.

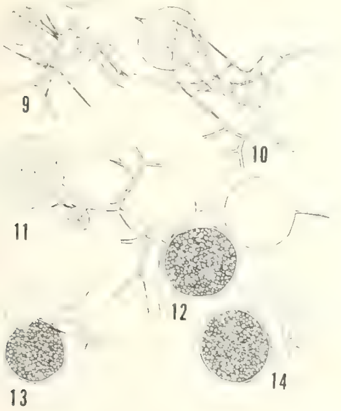
The paper further defines the botanical nature of a "false truffle," a fungus with habits similar to a truffle, but in a different class. A widely distributed mycorrhizal fungus on Douglas-fir roots, the mycorrhiza is of special interest in forestry because it inhibits growth of several root pathogens, including *Poria weirii* and *Fomes annosus.*



Microscopic characteristics of Rhizopogon vinicolor *grown on photo dextrose agar.*

The Endogonaceae in the Pacific Northwest, by J.W. Gerdemann and James M. Trappe (118)

Research on mycorrhizae has been advanced by a report on the mycorrhiza-forming fungi of the family Endogonaceae (pronounced en-doe-go-nay-cee-ee). This work, completed in cooperation with the University of Illinois, will enable researchers to determine which of the 44 known species of Endogonaceae they are working with, or if they are dealing with a new species. These fungi, which form vitally needed mycorrhizae with nearly 95 percent of the world's plant species, could not previously be identified.



Developmental stages in the formation of azygospores of Acaulospora laevis.

The book on Endogonaceae is particularly timely as interest in reforestation and containerized seedlings has grown. Researchers are already at work to develop the methodology for inoculating nursery seedlings with beneficial fungi. This was very difficult before development of soil fumigation technology because the soil must be sterilized first. Otherwise the beneficial fungi would be crowded out by competing resident micro-organisms.

Sporocarps of Endogone.

Germination of Spores of *Glomus macrocarpus* (Endogonaceae) After Passage Through a Rodent Digestive Tract, by J.M. Trappe (119)

Many mycorrhizal fungi, including truffles and false truffles fruit underground. Such species are widespread in Pacific Northwest forests. They have no mechanism to discharge their spores to the air for wind dispersal. Rather, they depend on being dug up and eaten by small mammals such as squirrels, deer, mice, and voles. The mammals digest all of the fruiting bodies except the spores, which are passed out in fecal pellets—small "packages" of viable spores mixed with nitrogenous animal wastes. Rains then wash the spores into the soil, where they can germinate in contact with tree roots to form new mycorrhizae. Many small mammals that have a bad reputation as tree seed eaters thus also help new seedlings become established by dispersing mycorrhizal fungi. For further information on subterranean fungi, see the bibliography (120).

For other reports on mycorrhizae, see the bibliography for this section (121).

The Higher Fungi of Oregon's Cascade Head Experimental Forest and Vicinity, by Alexander H. Smith and James M. Trappe (122)

In the fall of 1970, two mycologists joined forces to explore the forest fungi of Cascade Head on the central Oregon coast. Both are internationally recognized authorities on taxonomy of mycorrhizal fungi.

Cascade Head is a perfect "garden spot" for fungi because of the varied environments and the wet, moderate year-long climate. The scientists checked up and down the coast, along stream valleys, and made frequent visits to various forest types, sand dunes, pastures, and the many shrub types. The result was a huge collection of fungi. Smith's collection numbers 1,440 specimens, while Trappe has collected nearly 1,000 from the same area.

This publication lists some of the fungi found, including nine new species or varieties. Many are undoubtedly mycorrhizal.

- *Established procedures required for the production and purification of a naturally occurring virus of the tussock moth and demonstrated its safety to nontarget organisms.*
- *Conducted experiments to test aerial sprays of the virus and a bacterium for control of tussock moths.*
- *Studied the natural effects of the virus on tussock moth populations in the woods.*

Thompson is most enthusiastic about the virus because it works against the tussock moth in nature. The bacterium (Bacillus thuringiensis, *or* BT) *will kill tussock moths and is commercially available, but it is not a part of their natural ecosystem. Both micro-organisms, however, have demonstrated considerable promise as safe, sound tools for pest management.*

The virus is particularly potent, Thompson says. The tussock moth larvae eat the virus while feeding on tree foliage. As the virus mutliplies and spreads through the larva, it causes a degenerative disease which kills the insect. A larva which has been killed by virus dissolves into a messy residue that's highly infectious to other insects.

In nature, the virus contributes to the collapse of tussock moth outbreaks—usually on a 3-year cycle. "We believe the virus plays an important role in the termination of most outbreaks," Thompson says. "We don't always find virus in the early stages of an outbreak. If we do, it's at a very low level. The virus is probably there, but at such low levels that it is hard to locate."

Last year, the third year of the cycle in the original Blue Mountain outbreak, the virus was much more prevalent. It came in too late to prevent severe defoliation, but the principle still holds. "Everything we know about the tussock moth points to a pattern of outbreak and decline—usually on a 3- to 4-year basis. And the virus usually plays an important role."

The virus is not the only natural control factor, but is "one we can readily manipulate," Thompson says. Other factors which contribute to the collapse of tussock moth outbreaks are climatic conditions, parasites and predators, and food supply for the insects.

One of the first questions that comes up about viruses is safety. Could they be harmful to wildlife or to man when sprayed in

Insect Mycophagy: A Preliminary Bibliography, by Robert Fogel (123)

Little is known about the insects that eat fungi. They are important because they are probably responsible or contribute to the spread of many forest diseases, including *Poria weirii.*

Scientists know, for example, that *P. weirii* is just loaded with insects. Some are beetles which could carry spores of the disease to the roots of trees.

This is a bibliography—a beginning point for anyone interested in this highly specialized subject.

Generic Synonyms in the Tuberales, by James M. Trappe (124)

Like other areas of science, fungal taxonomy is a continuing process. Concepts and conclusions often change as more and better data become available. "New" species found in different parts of the world often later prove to be one and the same. For example, one species had previously been known by eight different names. To bring order out of such confusion, Trappe has examined literally thousands of specimens in herbaria in nine different countries.

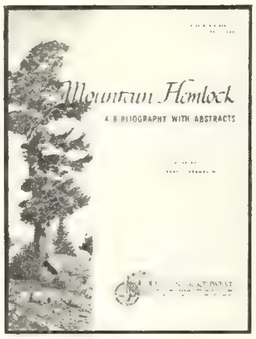
This particular paper deals with the taxonomy of important mycorrhizal fungi in the Tuberales—the epicurean delight otherwise known as truffles!

Pure Culture Synthesis of Bearberry Mycorrhizae, by B. Zak (125)

Foresters have noticed that bearberry *(Arctostaphylos uva-ursi)* and Pacific madrone *(Arbutus menziesii)* are often good nurse plants for pine and Douglas-fir reproduction. Careful laboratory experiments provide an explanation for this phenomenon. Several fungi that form mycorrhizae with the conifers also form mycorrhizae with bearberry and madrone. When a tree seed germinates near a bearberry or madrone, the seedling's roots grow down to contact compatible mycorrhizal fungi. Its rootlets can "plug in" to the mycorrhizal system of the nurse plant rather than having to compete with the nurse for soil nutrients.

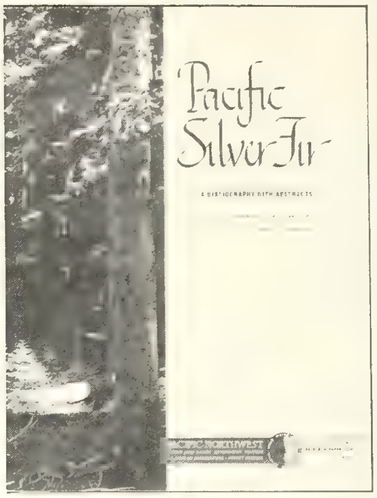
Shrubs such as vine maple form mycorrhizae with fungi that are not compatible with most conifers. The seedling started under vine maple must compete directly with it rather than form a friendly relationship. For an additional source of information on pure culture synthesis, see the bibliograpy (126).

high elevation management



Mountain Hemlock, A Bibliography With Abstracts, by Jerry F. Franklin (127)

A 50-page bibliography that lists references to mountain hemlock from North American and European literature. An attempt has been made to include all references which might provide useful information on this species. Abstracts are provided for those considered most significant.



Pacific Silver Fir, A Bibliography With Abstracts, by Carroll B. Williams, Jr., and Jerry F. Franklin (128)

Researchers found references as far back as 1855 to include in this 84-page bibliography on Pacific silver fir. Titles are included from North American and European literature. An attempt has been made to include all references which might provide useful information on this species. Abstracts are included for those considered most significant. The report includes a subject matter index and a list of common and scientific names of tree species mentioned in the bibliography.

Elevation Affects Timber Growth

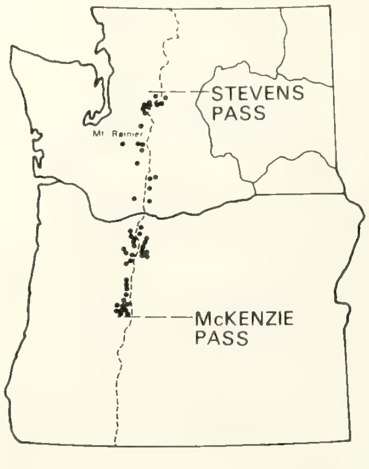
The potential timber productivity of the high-elevation forests of the Cascades can be more accurately estimated because of studies by three PNW mensurationists. As road systems have improved and management has intensified, these forests have become more important for timber production.

The mensurationists have found that height growth patterns of Douglas-fir on the west slope of the Cascades between 2,000 and 5,000 feet differ from growth patterns of the same species at lower elevations. Use of site index curves developed from data from low-elevation stands will tend to overestimate productivity of old stands and underestimate that of young stands. Lower temperatures and a shorter growing season apparently produce slower early growth and more prolonged growth in later life. Noble fir and possibly other associated species show similar patterns.

In two reports in *Forest Science* in 1974, Bob Curtis, Francis Herman, and Don DeMars present a new method of constructing site index curves and new information on height growth of Douglas-fir in these upper-slope forests (129). The reports are *Which Dependent Variable in Site Index-Height-Age Regressions?* and *Height Growth and Site Index for Douglas-fir in High Elevation Forests of the Oregon-Washington Cascades.*

Information presented indicates that the height growth pattern of Douglas-fir at high elevations differs from that for lowland Douglas-fir. Corresponding differences exist in the pattern of volume growth. Researchers indicate that site index curves developed for lowland Douglas-fir should not be used to predict growth rates (and allowable cuts) at higher elevations as they may result in erroneous estimates of growth potential.

The height growth curves presented here can be used to predict growth within the geographic and elevational zone represented by the data—the Oregon and Washington Cascade Range between Stevens Pass and McKenzie Pass at elevations above about 2,500 feet.



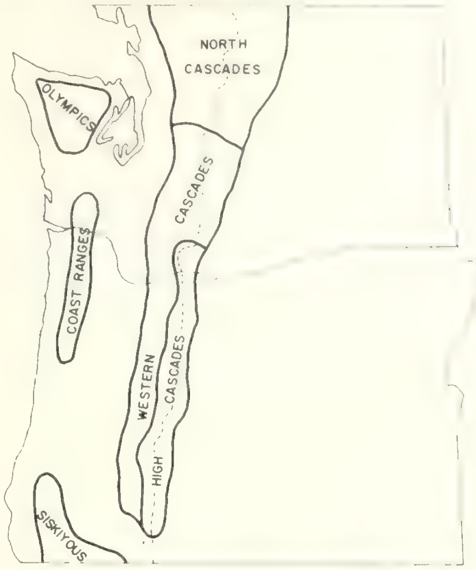
Geographic distribution of Douglas-fir stem analysis study locations in Oregon and Washington.

Ecology and Silviculture of the True Fir-Hemlock Forests of the Pacific Northwest, by Jerry F. Franklin (130)

The "true fir-hemlock forests" occur at middle to high elevation in the Cascade and Coast Ranges of Oregon and Washington. These forests are typified by such species as Pacific silver fir, noble fir, Shasta red fir, subalpine fir, mountain hemlock, and western white pine. The forests cover in excess of 3,000,000 acres in the Pacific Northwest and are one of the region's most important orest resources.

Until recently, this complex of forest types was relegated to relative obscurity by the Douglas-fir forests on western slopes of the Cascade Range. In the past decade, however, this has changed dramatically. Species previously considered "weed" trees now command major attention from practicing foresters.

This report, presented at the 1964 meeting of the Society of American Foresters in Denver, Colorado, is an introduction to the true fir-hemlock forests, the environment they occupy, management systems presently in use, and problems encountered in management and utilization of the resource.



The six major geologic areas in which true fir-hemlock forests occur. Crest of the Cascade Range indicated by a dotted line.

Natural Reproduction of Grand Fir and Mountain Hemlock After Shelterwood Cutting in Central Oregon, by K.W. Seidel and R. Cooley (131)

Although based on a single case history, the information presented here should prove useful as a basis for determining how many trees to leave when using the shelterwood method in upper-slope fir-hemlock stands in the central Oregon Cascades.

It is apparent from the study that grand fir and mountain hemlock seedlings require a considerable amount of overstory protection in order to live through the first 2 years after germination. In order to get satisfactory numbers of grand fir seedlings, residual stand density should be no less than about 80 ft^2 per acre.

Mountain hemlock is more sensitive to microclimatic extremes than grand fir and more vulnerable to windthrow. As a result, overstory density should be even higher in this species (more than 100 ft^2 per acre) if hemlock makes up a large percentage of the stand. The tallest, large-crowned trees should be kept to minimize loss from windthrow.

Trees Invade Subalpine Meadows

In the past, meadows of the forest-tundra region of the Washington and Oregon Cascades have been invaded by a variety of tree species, most notably subalpine fir and mountain hemlock. The heaviest invasion occurred between 1928 and 1937, with very little since about 1945.

The authors discuss various reasons for the encroachment of forest on meadows, including fire and grazing, but suggest that climatic change is the most probable cause. A relatively dry period occurred late in the nineteenth century and extended into the 1940's. This caused the glaciers to retreat and lengthened the snow-free period in high mountain areas.

For an interesting discussion read, *Invasion of Subapline Meadows by Trees in the Cascade Range, Washington and Oregon,* by Jerry F. Franklin, William H. Moir, George W. Douglas, and Curt Wiberg (132).

Distribution of invading seedlings and saplings and of older family tree groups on the 0.8-ha study tract in Paradise Valley, Mount Rainier National Park, Wash.

the forest? Extensive safety tests are required by the Environmental Protection Agency before a material can be registered for use. Most of this work has already been done. Dr. Mauro Martignoni, a microbiologist on Thompson's staff, has directed preliminary tests on rabbits, rats, mice, deer, quail, fish, and bees—and none were harmed by the virus. The work with rabbits and fish has been done in the Corvallis laboratory. Other work has been contracted or conducted by the U.S. Department of the Interior's Fish and Wildlife Service.

According to Thompson, viruses are "among the more specific pathogens. A good many have only one host." The virus Thompson's team is working with is a nucleopolyhedrosis virus, of which there are several hundred varieties. Most of these viruses cause diseases of the larvae of the tussock moth and other Lepidoptera such as the cabbage looper, cotton bollworm, forest tent caterpillar, and hemlock looper. The specific virus under study is infectious to only a few closely related species of tussock moths.

Working from electron microscope pictures, researchers have identified at least three distinct viruses that kill the tussock moth. One, a bundle virus, was selected for intensive studies, primarily because it seems to cause greater breakdown of the larvae, says Kenneth Hughes, a research entomologist on Thompson's staff.

Hughes, who has studied hundreds of electron microscope pictures of the virus, talks about its structure: the virus comes in bundles with anywhere from 1 to 20 individual virus rods per bundle. The bundles, surrounded by lipo-protein membranes, are grouped into a polyhedron. Because it acts as a protective device, the polyhedron enables the virus to survive in the environment. Without the polyhedron, the virus breaks down quickly and is destroyed in sunlight. Enclosed in the polyhedron, the virus can last for years—perhaps indefinitely—if conditions are ideal.

Ask Hughes if the virus is alive, and he gets a quizzical look on his face. "The polyhedron is a protein crystal," he says. "It grows as a crystal grows. If virus particles are there, they are incorporated in it. They reproduce, but so do other complicated chemicals not generally thought of as living."

"Perhaps we're at the shady margin where it isn't even appropriate to make a distinction," he says.

Seasonal Height Growth of Upper-Slope Conifers, by Carroll B. Williams, Jr. (133)

This paper is the first published information available for seasonal height growth for some of the principal middle- to high-elevation species of the Cascade Range in the Pacific Northwest. Observations are given for subalpine fir, noble fir, Pacific silver fir, Douglas-fir, western white pine, lodgepole pine, western hemlock, mountain hemlock, and western redcedar.

Total height growth seemed to be related to length of current growing season, particularly for the true firs and mountain hemlock. Significant variations were found in the study areas between species and by years for initiation of bud bursting, length of growing season, and stages of growth completion.

Subalpine fir in foreground.

Seeding Habits of Upper Slope Species

Several papers have been published under the title, *Seeding Habits of Upper-Slope Species.* These include:

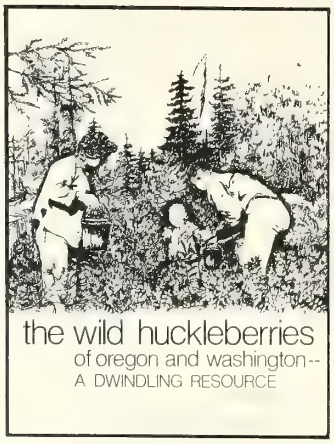
I. *A 12-Year Record of Cone Production* (134), by Jerry F. Franklin, Richard Carkin, and Jack Booth. This is a 12-year study of cone production by noble, Pacific silver, grand, white, subalpine, and Shasta red firs, mountain hemlock, western white pine, and Engelmann spruce. Upper slope species produced medium to heavy cone crops at 2-3 year invervals at most locations.

II. *Dispersal of a Mountain Hemlock Seedcrop of a Clearcut* (135), by Jerry F. Franklin and Clark E. Smith. Mountain hemlock seedfall declined rapidly beyond 125 feet from the stand edge, but central portions of a 30-acre clearcut still received large amounts of seed. Seedling germination or establishment appears to be the major problem in regenerating mountain hemlock on clearcuts.

Western white pine in a mixed stand of Douglas-fir, western larch, western white pine and hemlock.

III. *Dispersal of White and Shasta Red Fir Seeds on a Clearcut* (136), by Jerry F. Franklin and Clark E. Smith. Very heavy seed crops occurred in 1968 and 1971 in white and Shasta red fir stands. Southwesterly winds were most important in seed dispersal. As a result, shelterwoods and strip clearcuts should be elongated northwest-southeast to provide the best assurance of adequate seed supply.

Mountain hemlock on Mt. Adams near Bird Creek Meadows



the wild huckleberries
of oregon and washington--
A DWINDLING RESOURCE

The Wild Huckleberries of Oregon and Washington, a Dwindling Resource, by Don Minore (137)

An estimated 160,000 acres support huckleberries in Oregon and Washington, but this area is dwindling as trees and shrubs invade the berry fields. Effective vegetation-control methods and huckleberry management techniques have not been developed. However, such techniques are available for the closely related eastern blueberries, and it may be possible to modify these methods for northwestern conditions.

The Twin Buttes huckleberry field is probably the most productive of the 160,000 acres of wild huckleberry land in Oregon and Washington. The 1969 season was unusually favorable near Trout Lake, Washington, producing an estimated berry harvest of 280,000 gallons—or 112 gallons per acre. With these berries valued at $3 per gallon, the economic yield was over $300 per acre for that single year. In addition, recreational benefits also were enjoyed by the berry pickers, who spent 163,000 visitor days on the Twin Buttes huckleberry field during the 1969 season.

Even half of the 1969 huckleberry yield at Twin Buttes would equal or exceed the value of timber produced annually on most high-site forest land, and the Twin Buttes huckleberries grow on a poor site. In fact, most huckleberry fields apparently occupy sites that are only marginal for timber production. The most productive fields seem to occupy the poorest timber-growing lands.

This publication is the first step in a research program aimed at developing management techniques that can be used to conserve and develop the huckleberry resource. It summarizes available information on native northwestern *Vaccinium* species and their management. Management techniques for eastern *Vaccinium* species also are summarized.

Several notes on this research have also been published. See also articles listed under (138).

Tentative Ecological Provinces Within the True Fir-Hemlock Forest Areas of the Pacific Northwest, by Jerry F. Franklin (139)

True fir-hemlock forests occupy extensive areas at middle to high elevations in mountainous regions of Oregon and Washington. These forests are characterized by Pacific silver fir, noble fir, Shasta red fir, subalpine fir, western hemlock, mountain hemlock, and western white pine. True fir-hemlock forests constitute a major forest resource, covering approximately 3 million acres and containing about 100 billion board feet of timber. They occupy the upper reaches of many major drainages, occur within summer ranges of big-game animals, and in many areas receive heavy recreational use. True fir-hemlock forests vary a great deal in species composition and stand characteristics and will require a variety of silvicultural prescriptions for intensive management.

This paper suggests useful geographic divisions of the true fir-hemlock forests within the mountainous regions of western Oregon and Washington. Divisions are based on differences in geology, topography, soil parent materials, climate, and forest composition. Because the regions or provinces are based on a consideration of several factors rather than just a single factor such as physiography or climate, they are considered ecological provinces. The provinces provide a geographic framework which facilitates isolation and solution of management problems and provides an initial stratification for research purposes.

animal damage

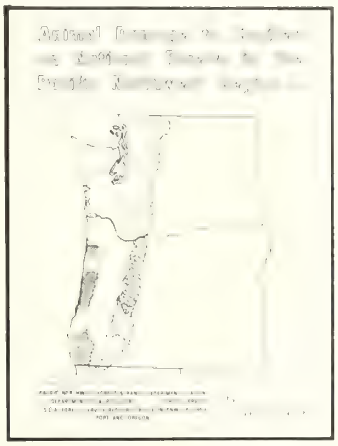
general

A survey of animal damage to forest plantations in Oregon and Washington was begun in 1963, under the direction of the Cooperative Animal Damage Survey Committee. The survey was scheduled to end in 1969. Cooperators installed a series of 112 sampling plots in plantations during 1963-64 and a second series of 82 during 1964-65. Of these plots, 165 are on Douglas-fir plantations, 4 are in mixed Douglas-fir and ponderosa pine, and 25 are in ponderosa pine and Jeffrey pine, or mixtures of the two.

We found a significant amount of mortality, unrelated to animal damage, soon after planting. But, based on differences between survival of caged and uncaged seedlings, animals caused 35 percent of the mortality in Douglas-fir, 51 percent in the pines.

Animals damaged seedlings on all plots. Browsing and clipping of stems were the principal causes of seedling injury. Cutting of roots, budding, barking, trampling, pulling seedlings from the ground, and covering seedlings with soil were also noted. Browsing by deer was the most common source of animal damage on all plots. Animals that injured seedlings, ranked by frequency of damage in 1968, were big game, hares and rabbits, grouse, mountain beavers, pocket gophers, domestic stock, porcupines, microtine rodents, and moles.

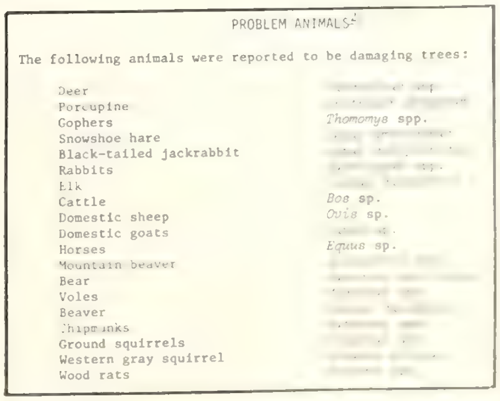
Survey of Animal Damage on Forest Plantations in Oregon and Washington, by Hugh C. Black, Edward J. Dimock II, Wendell E. Dodge, and William H. Lawrence (140).



Animal Damage to Conifers on National Forests in the Pacific Northwest Region, by Glenn L. Crouch (141)

This study was conducted to provide an assessment of animal-conifer problems on national forests in the Pacific Northwest. Information was gained through questionnaires mailed to ranger districts. The study reports data on: (a) kinds of damage, (b) species of animals causing damage, (c) locations of problems, and (d) related management factors.

Regionally, browsing of young seedlings by deer, elk, and livestock was the most serious problem. Removal of bark by porcupines, bear, and other animals was second in importance.



PROBLEM ANIMALS1/

The following animals were reported to be damaging trees:

Deer	[illegible]
Porcupine	[illegible]
Gophers	*Thomomys* spp.
Snowshoe hare	[illegible]
Black-tailed jackrabbit	[illegible]
Rabbits	[illegible]
Elk	[illegible]
Cattle	*Bos* sp.
Domestic sheep	*Ovis* sp.
Domestic goats	[illegible]
Horses	*Equus* sp.
Mountain beaver	[illegible]
Bear	[illegible]
Voles	[illegible]
Beaver	[illegible]
Chipmunks	[illegible]
Ground squirrels	[illegible]
Western gray squirrel	[illegible]
Wood rats	[illegible]

The structure of the virus also affects the way it acts inside the tussock moth. In feeding, the tussock moth eats not only the virus, but also the polyhedra which enclose them. When the polyhedra reach the midgut of the insect, they come in contact with an alkaline solution, which dissolves the protein base of the polyhedron and allows the virus to spread through the insect's bloodstream.

Researchers don't really know what happens after that. Hughes would like to know, and perhaps one day the pictures will yield a clue. But right now, the important thing is that the virus does the job. Somehow, the virus is transmitted to various parts of the insect, where it multiplies, breaks down cell tissue, and eventually kills the insect.

end

A RECIPE FOR CLEANER CAMPGROUNDS

by Thomas Michael Baugh

Children in national forest campgrounds throughout the Pacific Northwest have become litter fighters. These young anti-litter bugs are helping to reverse an expensive and highly objectionable trend. Instead of tossing a candy wrapper or empty can on the ground, the new generation picks up discarded trash, places it in a bag provided by the campground attendant, and turns the bag in for a well-earned reward.

Most observers agree that traditional approaches to controlling litter have not worked. The litter continues to build up, and campground workers spend long hours and public dollars cleaning up the debris.

In 1971, researchers in a Seattle unit of the Pacific Northwest Forest and Range Experiment Station began investigations into the control of litter. The PNW scientists, Roger Clark and John Hendee, together with Robert Burgess, a Univeristy of Washington sociologist, not only learned a lot about why people litter, but also developed and tested an incentive system aimed at solving the litter problem.

The initial research took place in two movie theaters in the Seattle area. Clark points out that movie theaters were an ideal starting point, because most movie-goers feel that it is okay to throw empty popcorn bags and boxes on the floor.

Destruction of Conifer Seed and Methods of Protection, by M.A. Radwan (142)

Unlike many deciduous tree species which are easily propagated vegetatively, most conifers are reproduced naturally and artificially from seed. Success of conifer forest regeneration, therefore, depends on production of sufficient quantities of high quality seed. This can be achieved only by thorough knowledge of factors affecting seed production and protection of the seed crop from natural destructive agents.

Presently, the trend in artificial reforestation is toward planting rather than direct seeding. However, seeding will probably remain the more economical and perhaps the only suitable reforestation method in many situations. The overall problem of seed destruction and methods of protection, therefore, are reviewed in this paper to guide present and future reforestation efforts with conifer seed.

Coating and Impregnating with Endrin Protects Field-Sown Douglas-fir Seed, by G.L. Crouch and M.A. Radwan (143)

Artificial seeding is a useful means of reforestation under suitable conditions, but the probability of success is variable and dependent upon a multitude of uncontrollable physical and biological interactions. Regardless of other variables, the writers reaffirm their belief that Douglas-fir seed sown at 1.12 kg or less per hectare must be protected with endrin or another equally effective chemical if seeding is to have a reasonable chance for success.

M A. Radwan

Natural Resistance of Plants to Mammals, by M.A. Radwan (144)

A report on some of the problems involved in determining the chemistry of resistance to browsing of forest trees by animals. There is much evidence to show that resistance occurs among and within plant species. But determining precisely what chemical factors are responsible for that resistance is very difficult.

For a general discussion of research by PNW scientists at Olympia, Washington, see also an article titled, "What makes Deer Choosy Eaters?" in the February 1975 issue of *Forestry Research: What's New in The West* (145).

Animal Resistant Douglas-fir

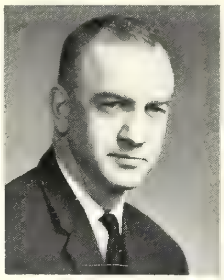
When asked about reducing animal damage to planted conifers, research forester Ned Dimock reports that the way is now clear for exploiting genetic resistance in Douglas-fir. Working with forest geneticist Roy Silen and forestry technician Virgil Allen, Dimock showed that both captive black-tailed deer and snowshoe hare would select among Douglas-fir clones while feeding on tree foliage. Preferences for similar appearing but genetically different foliage samples approached a ratio of 5:3 for deer and exceeded 5:2 for hare. In addition, deer and hare showed both parallel and differing preferences for genetically identical material.

Crossing resistant parents produced seedlings that also resisted deer browsing and hare clipping in controlled tests with captive wild animals. Differences between susceptible resistant progenies were on the order of 2:1. Such animal resistance is strongly inherited. Resistance is predictable with a reasonably high degree of accuracy—close enough to minimize the need for progeny tests if parental resistance characteristics are determined.

How effective is resistance in protecting seedlings planted in areas susceptible to heavy animal damage? "Highly so," says Dimock, "if we can base conclusions on our experience with snowshoe hare—a species that can heavily damage small seedlings. In two different field tests, we found that resistant families were only clipped about half as much as susceptible ones during periods of most severe damage. In both cases, we got effective protection for a whole year—and, in one case, natural resistance was effective for 2 years, the longest time we've monitored it."

Rating Douglas-fir parents for damage resistance is easy in theory—but difficult in practice due to the need for special facilities, carefully controlled testing methods, plus sufficient time and money to achieve reliable results. Also, Douglas-fir genotypes resistant to one animal species may not be resistant to another. However, with increasing attention being paid to improving genetic strains of valuable conifer crops, animal resistance should be a trait worth developing. From what we know so far, it is a trait that seems entirely compatible with rapid growth, good stem form, and other characteristics usually sought after in tree breeding.

For further details, consult *Animal Resistant Douglas-fir: How Likely and How Soon?* (146) by Edward J. Dimock, and *Genetic Resistance in Douglas-fir to Damage by Snowshoe Hare and Black-Tailed Deer* (147), by Edward J. Dimock, Roy R. Silen, and Virgil E. Allen.

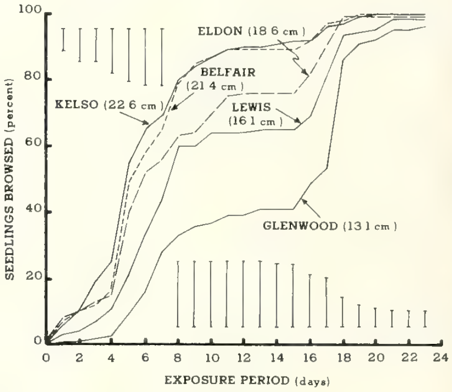

Ned Dimock

deer and elk

Seedling Height and Deer Browsing

In a study near Olympia, Washington, researchers tried to determine if Douglas-fir seedlings from different sources would be browsed differently by deer. Results were interesting. In the preliminary analysis, it looked as though feeding preference differed markedly among the races tested. But more complete results later indicated that feeding preferences were strongly linked to seedling height. Even that conclusion is probably a simplification. In all likelihood, both height and qualitative variations affect browsing preference.

See *Influence of Douglas-fir Seedling Height on Browsing by Black-Tailed Deer,* by Edward J. Dimock II (148).



Browsing preference by black-tailed deer for Douglas-fir seedlings from five western Washington races.

Plant Characteristics Related to Feeding Preference by Black-Tailed Deer, by M.A. Radwan and G.L. Crouch (149)

Like other herbivores, black-tailed deer show definite selectivity in their feeding. Thus, the animals have often been observed to prefer different parts of plants and to have preferences among and within species.

Many investigations have been made of the causes for these differences. Most, however, have dealt with nutritive value as a preference factor, the theory being that wildlife browse species that will be most nutritious.

Not so, says chemist and plant physiologist M.A. Radwan. He thinks that's a lot of nonsense. This publication is an attempt to resolve the literature on that point.

Vegetation and Soils of a 30-year Deer and Elk Exclosure in Central Washington, by A.R. Tiedemann and H.W. Berndt (150)

Study of the soils and vegetation surrounding a 1-acre deer and elk exclosure in eastern Washington has enabled ecologists to learn more about the effect of wildlife on soil and vegetation. The study site was in and around an exclosure established in 1939 near Wenatchee.

The striking contrast in vegetation within and outside the exclosure drew scientists' attention to the site. The area inside the exclosure supports a dense stand of snowbrush ceanothus. Grasses and forbs dominate the understory outside the exclosure.

The researchers discuss the soil and vegetation of areas inside and outside the exclosure. Their results, of course, point out the continued increase in biomass and litter within the exclosure. But they also indicate that heavy use by wildlife was not enough to affect soil nutrient levels or soil stability. Only vegetative composition, plant crown cover, and litter accumulation have been affected.

Terpenes May Also Affect Browsing

Two large groups of chemicals—the phenols and terpenes—appear to affect browsing preference in Douglas-fir. Work on the phenols is summarized in the preceding note. In this study, researchers measured the monoterpene hydrocarbons in foliage vapors from four Douglas-fir clones—two that were resistant to browsing and two that were not. With all methods used, more terpenes were found in foliage that was resistant to browsing. Results are preliminary, but may have application in breeding Douglas-fir resistant to browsing.

See *Clonal Variation in Monoterpene Hydrocarbons of Vapors of Douglas-fir Foliage*, by M.A. Radwan and W.D. Ellis (151).

	Peak height (cm) [illegible]							
	Clone SD 19		Clone SD 10		Clone SD 22		Clone SD 13	
Component	Range	Mean	Range	Mean	Range	Mean	Range	Mean
				A. In presence of air				
α pinene	123-163	135	42-52	47	130-202	162	[illegible]	[illegible]
Camphene	4-9	7	1-3	2	6-11	8	4-[illegible]	8
β pinene	128-170	150	37-50	42	227-339	275	166-243	[illegible]
Sabinene	12-44	33	6-50	33	12-63	42	[illegible]	[illegible]
Δ 3 carene	[illegible]-68	51	100-120	109	48-64	57	60-[illegible]	98
Myrcene	1-18	6	1-10	4	1-3	2	1-68	27
Limonene	8-12	10	2-4	3	10-18	13	6-15	11
β phellandrene	2-6	4	2-6	4	4-8	6	5-16	[illegible]
γ terpinene	2-11	5	2-10	6	3-9	6	6-32	20
Terpinolene	4-8	6	6-10	8	6-10	8	16-31	24
Total terpenes	[illegible]-484	430	269-303	280	521-720	610	[illegible]-974	805
				B. In presence of nitrogen				
α pinene	114-232	173	43-80	66	152-208	166	206-410	266
Camphene	5-13	8	2-4	3	6-12	[illegible]	5-13	8
β pinene	102-262	173	30-74	55	162-[illegible]	[illegible]	162-406	222
Sabinene	44-59	53	42-96	74	27-106	56	63-[illegible]	153
Δ 3 carene	18-84	54	83-187	142	24-106	79	[illegible]-248	131
Myrcene	14-26	19	1-65	26	2-29	12	1-13	[illegible]
Limonene	12-20	14	3-7	5	13-24	18	12-20	15
β phellandrene	4-8	6	4-10	6	5-8	6	11-22	14
γ terpinene	2-13	6	2-17	6	2-11	6	8-36	23
Terpinolene	6-13	8	12-20	14	7-14	11	21-48	29
Total terpenes	685-1005	800	507-740	671	688-1116	924	874-1780	1126

[a] Year old foliage sampled during winter. SD 19 and SD 10 susceptible to browsing, SD 22 and SD 13 resistant.

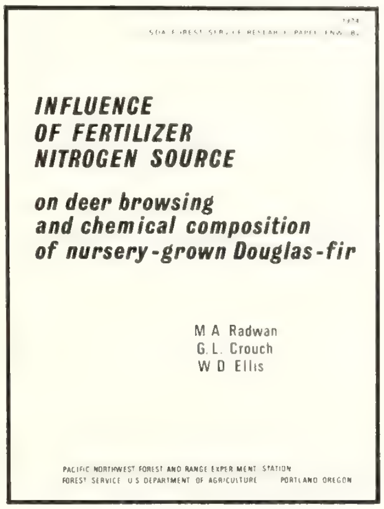
[b] Separated on a capillary column. Total terpenes include all unknowns. Figures rounded to nearest cm; represent five composite samples.

Monoterpenes of vapors from whole foliage of Douglas-fir.

Chlorogenic Acid Linked to Browse Resistance

A phenolic compound, chlorogenic acid, appears to be involved in deer browsing preference in Douglas-fir. In studies, deer consistently browsed tree foliage that is high in chlorogenic acid. Deer are also known to prefer mature Douglas-fir which is higher in chlorogenic acid than that of young seedlings.

For papers on this topic, see (152) in the bibliography.



1974

USDA FOREST SERVICE RESEARCH PAPER PNW-[illegible]

INFLUENCE
OF FERTILIZER
NITROGEN SOURCE

on deer browsing
and chemical composition
of nursery-grown Douglas-fir

M.A. Radwan
G.L. Crouch
W.D. Ellis

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE PORTLAND, OREGON

Effects of Fertilizer on Browsing

Results of one study indicate that the type of nitrogen fertilizer has no effect on browsing preference by deer in Douglas-fir. One-year old Douglas-fir seedlings were fertilized with ammonium sulfate, calcium nitrate, and urea. Seedlings from the different treatments were browsed with equal vigor by penned deer.

Influence of Fertilizer Nitrogen Source on Deer Browsing and Chemical Composition of Nursery-Grown Douglas-fir, by M.A. Radwan, G.L. Crouch, and W.D. Ellis (153).

Interaction of Deer and Forest Succession on Clearcuttings in the Coast Range of Oregon, by Glenn L. Crouch (154)

The author reviews the history of man's interest in deer and forest succession. Deer by themselves can slow the return of Douglas-fir on clearcuts in the Pacific Northwest region, but do not delay succession for long—unless their use is extremely heavy.

Repetitive browsing by deer in combination with hare or mountain beaver, however, can definitely cause regeneration failures. Since tighter hunting regulations are unlikely for those areas, some type of physical or chemical control is necessary if reforestation is desired.

Saturday matinees, with their large audience of children, were selected for the theater phase of research. Over a 14 week period, researchers handed out litter bags, increased the number of trash cans and made them more conspicuous, and showed a short film with a strong anti litter message. Littering behavior was measured, in order to determine the response of the viewing audience to these traditional anti-litter measures. The results of this early work indicated that these conventional approaches did not work—almost half the litter remained on the floor.

In the next step, investigators implemented a system to reinforce anti-litter behavior. Children were offered several types of incentives for picking up trash and seeing that it was properly disposed of. With one group, the reward was a free ticket to a specially scheduled matinee; with another test group, the award was one thin dime. The results of the incentive system were impressive. Children in both test groups picked up more than 90 percent of the litter.

The Lake Kachess campground on the Wenatchee National Forest in Washington state was the scene for phase two of the research. Baseline data was again gathered in order to determine the amount and type of litter commonly found in the campground.

The researchers then approached 26 children from seven camping families and asked if they would like to help in a litter pickup program.

Animal Resistant Douglas-fir: How Likely and How Soon? by Edward J. Dimock II (155)

The author speculates on the future control of deer and hare browsing by genetic changes in Douglas-fir planting stock. Dimock is not optimistic that genetic control can be achieved in the near future. Research on feeding preferences has not shown either the consistency or the degree of variation that seems necessary for close genetic control. In fact, this research effort has now been shifted into other areas at the PNW Experiment Station on the assumption that it is relatively unproductive in both the short and long term.

Deer and Reforestation in the Pacific Northwest, by G.L. Crouch (156)

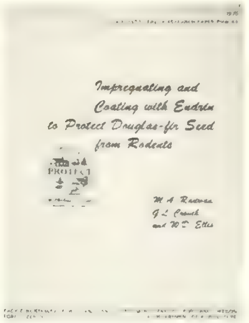
The author discusses the merits of managing deer and forests concurrently. In interior forests, browsing by mule deer often damages conifer seedlings planted on winter or transitional ranges. In the Douglas-fir region, numbers of black-tailed deer increase dramatically after forests are logged or burned, in response to improved forage supplies. Here, browsing on planted stock in clearcuts lowers forest productivity by reducing growth rates and occasionally contritributes to plantation failures.

Amelioration of damage by black-tailed deer could be achieved through long-range planning for concurrent deer and timber harvests, with hunting pressure directed to areas where logging promotes more deer.

small mammals

TMTD Wild Mammal Repellent: Review and Current Status, by M.A. Radwan (157)

Tetramethylthiuram disulfide, otherwise known as TMTD, is a very useful animal repellent, although further research is needed. This paper discusses its chemical properties, its use as a repellent against browsing and clipping animals, and limitations of the chemical.



Impregnating and
Coating with Endrin
to Protect Douglas-fir Seed
from Rodents

PROTECT

M A Radwan
G L Crouch
and W D Ellis

Impregnating and Coating With Endrin to Protect Douglas-fir Seed from Rodents, by M.A. Radwan, G.L. Crouch, and W.D. Ellis (158)

Endrin is evaluated as a chemical treatment for protecting tree seed from small mammals during reforestation operations. The chemical was applied to the seed both by coating and by impregnation.

Endrin remains the only chemical recommended for protecting seed from rodents, yet because of its toxicity should be replaced by true repellents as soon as possible. Results from this study also indicate that the endrin treatment now used should be improved. Doubling the endrin concentration would increase the effectiveness of the treatment, but researchers do not recommend that approach. Impregnation, which is more effective than coating, would be more desirable but more costly. Use of additives to increase the effectiveness of coatings should also be considered.

See also, *Factors Affecting Endrin Content of Endrin-Coated Douglas-fir Seed,* by M.A. Radwan and W.D. Ellis (159).

Protecting Forest Trees and Their Seed from Wild Mammals, by M.A. Radwan (160)

A research paper, published in 1963, reviews the literature on control of wild mammal damage to forest trees. Radwan discusses the methods used to control wild mammal damage to forest tree seed, seedlings, and trees. References to mammals causing the damage, their motivation, types of damage, and effect on the forest resource are given.

The review suggests that the damage is increasingly serious and the amount and scope of current research on control methods is still inadequate to overcome the problem.

Coating and Impregnating with Endrin Protects Field-Sown Douglas-fir Seed, by Glenn L. Crouch and Mohamed A. Radwan (161)

Endrin is a useful tool in treating for protecting Douglas-fir seed from deer mice. Observations from this study indicate that seedling production and stocking were much greater when the seed was treated with endrin. No differences were noted, however, when different endrin treatments were tested—for example, coating with endrin, using a combination of endrin and thiram, and by impregnating the seed with endrin.

Storing Endrin-Coated and Endrin-Impregnated Douglas-fir Seed, by M.A. Radwan and H.W. Anderson (162)

Results are reported on the effect of storing endrin-coated Douglas-fir seed. Application of endrin to Douglas-fir seed by coating at .5 percent or by soaking in endrin-dichloroethane solutions did not inhibit germination or seedling growth.

For other papers on chemicals to protect Douglas-fir seed from small mammals, see publications listed under (163).

Susceptibility of Ponderosa, Jeffrey, and Lodgepole Pines to Pocket Gophers, by Glenn L. Crouch (164)

Pocket gophers can be extremely damaging to young plantations of pines. In this study, the pesky creatures began to attack the pines almost immediately after planting. Within 3 hours, pocket gophers had walked off with several seedlings.

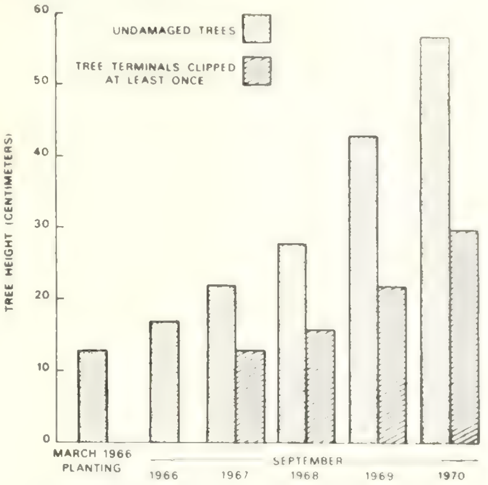
Trees were planted in March 1966. By September 1969, two-thirds of all the trees had been destroyed by gophers. Most of the damage occurred during the winter when the seedlings were presumably under snow.

Typical burned area adjacent to the study site, March 1966. Trees marked by cards were planted in 1962, damaged by gophers during the 1965-66 winter, and subsequently died.

ackrabbits Injure Ponderosa Pine Seedlings, by Glenn L. Crouch (165)

Black-tailed jackrabbits are present in many ands of ponderosa pine in central Oregon, specially where this forest type is interspersed with brush or grassland. In contrast to their sometimes damaging effect on agricultural crop or range lands, forestland jackrabbits appear to have little direct effect on tree crops except during forest regeneration. When, like their forest-dwelling counterpart, the snowshoe hare, they may damage tree seedlings.

Although apparently not widespread, damage to conifer seedlings by jackrabbits has been reported from Nebraska and central and eastern Oregon, but little quantitative information is available on mortality and height losses cause by these animals. This paper gives an account of injuries by jackrabbits to an experimental planting of ponderosa pine.

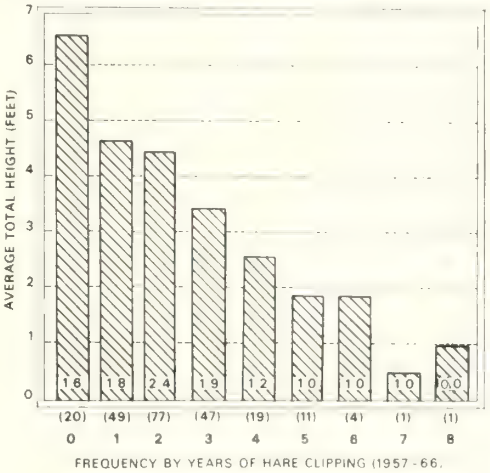


Heights of unclipped and clipped ponderosa pines through five growing seasons after planting. Differences in heights each year are significant at the 1-per cent level.

Ten-Year Height Growth of Douglas-fir Damaged by Hare and Deer, by Edward J. Dimock II (166)

A 10-year study of animal damage to Douglas-fir seedlings in Washington's coastal zone yields important information for forest land managers. Researchers suggest that in this area, planting of extra large trees may have dual benefits: (a) it will help get trees established and growing quickly enough to outdistance early browsing by hares, and (b) it should improve tolerance to western bracken.

Although both deer browsing and hare damage were reported, nearly all animal-caused losses were attributed to early damage by hare.



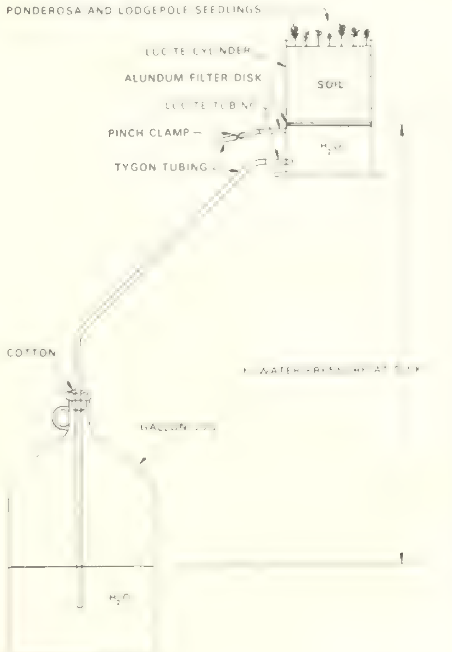
Height in 1966 of planted Douglas-fir seedlings as related to clipping frequency by hare.

effects of environment

Tolerance of Lodgepole and Ponderosa Pine Seeds and Seedlings to High Water Tables, by P.H. Cochran (167)

In south-central Oregon, there is a distinct type line between lodgepole and ponderosa pine. Stands of almost pure lodgepole pine grow on depressions and flat areas with ponderosa pine or a mixture of ponderosa and lodgepole growing on adjacent higher slopes. In this report, researchers analyze the possibility that this might be caused by differing tolerance of the two species to high water tables.

Results indicate that seeds and seedlings of both species have a surprisingly high tolerance to very wet soils and low oxygen diffusion rates. It is very likely that factors other than water table account for the difference in geographic preference of the species.



Apparatus for controlling soil water suction.

The children were told that in exchange for picking up litter they would be able to choose from rewards such as a Smokey the Bear comic book or shoulder patch, a Junior Forest Ranger badge, a small box of gum, a wooden ruler, or a "Keep Washington Green" pin. With litterbags clutched tightly in their small hands, the children worked through the campground. According to Clark, the results of this experiment and the many with followed suggested that litter can be reduced by about 75 percent when using this incentive system.

Campgrounds are obviously only a part of the total litter problem. Dispersed camping areas and hiking trails also accumulate litter. It was to one of these areas that the researchers next turned. Both the design of the study and the results were similar to the previous outdoor experiments. In the dispersed camping area, there was a 75 percent reduction from previous litter levels when the researchers offered incentives to the children of camping families.

Results such as those found by the PNW recreation research unit are of particular interest to land managers who face constantly rising costs and lower operating budgets. The practical applications of this simple incentive system have obvious esthetic and monetary advantages. Clark points out that an evaluation of one of the controlled experiments indicated that the incentive system was far more effective and much less costly than routine litter pickup by campground personnel. In one area, each bag of litter collected by Forest Service maintenance personnel cost about $8.30 in wages. Each bag of litter collected and turned in by one of

Don Minore

Water Tables Affect Tree Growth

Although lodgepole pine and western redcedar may be grown in areas with shallow water tables, they seem to grow best over deeper water tables. Red alder and Sitka spruce, also suitable for shallow water table areas, seem less suited to deep water tables. Douglas-fir is not tolerant of shallow water tables and should not be planted where water tables are near the surface.

Researchers caution that the absolute water tables discussed in this study are not directly comparable to water tables in forest areas. However, the relative tolerence of the species mentioned here should hold in forest regions.

See *Seedling Growth of Eight Northwestern Tree Species Over Three Water Tables,* by Don Minore (168).

More on Water Tables

In this study, plant ecologist Minore studied the effects of shallow water tables (skunk cabbage swamps and stream bottoms on the Olympic Peninsula) on four tree species—red alder, western redcedar, Sitka spruce, and western hemlock. Western hemlock cannot tolerate winter water tables less than 15 cm deep. Sitka spruce tolerates shallower water tables, but only where the water is flowing. Red alder and western redcedar seem little affected by water table, and grow reasonably well even where stagnant water is at or near the surface during the winter.

The absence of Douglas-fir on wet areas, even when surrounded by Douglas-fir trees, indicates that this species cannot tolerate shallow water tables.

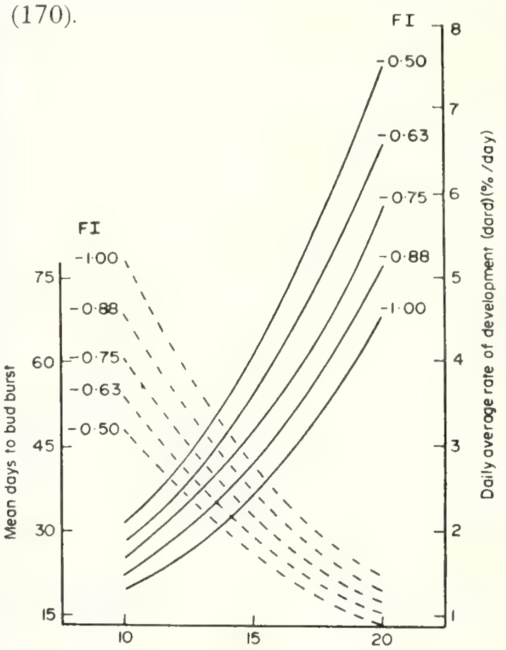
See *Occurrence and Growth of Four Northwestern Tree Species Over Shallow Water Tables,* by Don Minore and Clark E. Smith (169).

Seed Source Important

Transfer guides currently used for seed sources for reforesting Douglas-fir in western Washington and Oregon are rules of thumb taken from Swedish models.

This very technical paper presents a predictive model which uses timing of vegetative bud burst for examining reponses of seedlings to transfer. Results of a hypothetical transfer indicate that moving seed in east-west directions is less desirable than moving seed an equavalent north-south distance.

For details, see *Use of Phenology for Examining Provenance Transfers in Reforestation of Douglas-fir,* by Robert K. Campbell (170).



Mean days to bud burst and daily average rate of development towards bud burst as a response to mean daily temperature.

Shade Benefits Douglas-fir in Southwestern Oregon Cutover Area, by Don Minore (171)

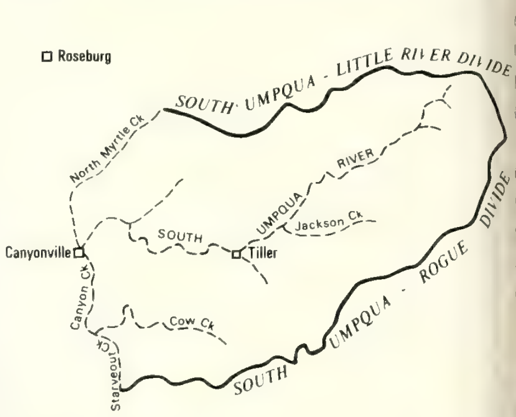
This experiment discusses the benefits of shade in improving the survival of young Douglas-fir trees planted in clearcut areas. On a hot, dry site in southwestern Oregon, shade is necessary for survival. The author discusses the relative merits of "dead" versus "live" shade. Dead shade is provided by nonliving materials such as rocks, piles of dirt, dead stumps, or logs. Live shade is provided by living things such as trees or shrubs. There appeared to be no difference between the benefits provided by each. It is the shade that is important.

Survival and growth of Douglas-fir seedlings, by treatment.

Treatment	Survival 1968	Survival 1969	Average height growth 1968	Average height growth 1969
	Percent	*Percent*	*Inches*	*Inches*
No shade	18.3	10.0	0	1.2
Live shade	56.7	46.7	.2	1.2
Dead shade	86.7	60.0	.3	1.6

Proposed Harvesting Guides Based Upon An Environmental Classification in the South Umpqua Basin of Oregon, by Richard E. Carkin and Don Minore (172)

Success or failure of forest regeneration on clearcuts is significantly related to soil depth and texture, elevation, solar radiation, moisture, and temperature of the preharvest environment. Regression equations are given which express these relationships. They should be useful in comparing potential regeneration difficulty on areas to be harvested.



Direct Solar Radiation on Various Slopes From 0 to 60 Degrees North Latitude, by John Buffo, Leo J. Fritschen, and James L. Murphy (173)

Solar energy is by far the most important climatic factor and is a significant parameter in ecological problems dealing with silviculture, entomology, pathology, and fire control.

In this report, computer programs were modified and written to calculate direct solar radiation on selected slopes and aspects in 10-degree increments from the Equator to 60 degrees north. These results are presented in tabular form and as graphical plots of hourly and daily values.

Columbus Day Windstorm Analyzed

The violent windstorm that occurred in the Pacific Northwest on October 12, 1962, was no lady. She caused more destruction in this region than any other windstorm in recorded history. In addition to lost lives and property damage, considerable damage was done to the area's forests. Blowdown of timber in the western parts of Oregon and Washington amounted to more than 11 billion board feet.

But what were the unique weather patterns that contributed to the big blow? Meterologists answer that question in a report: *Detailed Analysis of the 1962 Columbus Day Windstorm in Oregon and Washington,* by Robert E. Lynott and Owen P. Cramer (174).

competing vegetation

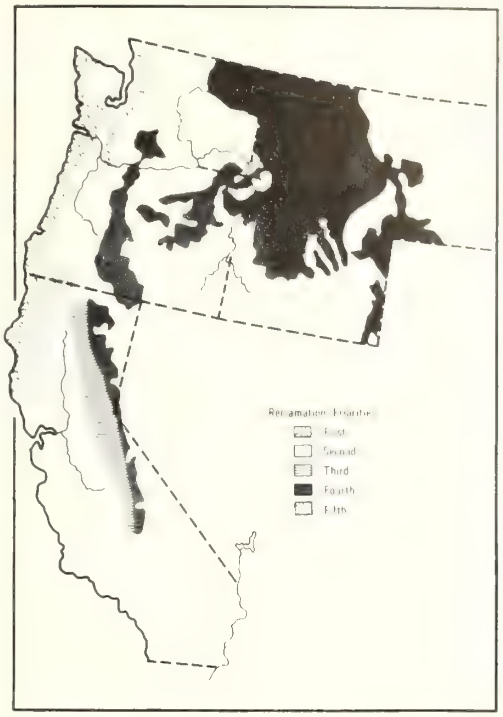
ehabilitation of Forest Land. The Pacific Coast and Northern Rocky Mountain Region, by H. Gratkowski, D. Hopkins, and P. Lauterbach (175)

here are about 96.7 million acres of commercial forest land in the Pacific Coast and orthern Rocky Mountain region. Of this, least 9 million acres are dominated by rush species and trees commonly condered ''weed species'' by foresters.

rush seems to be a problem throughout he region. For example, in the foothills of he Cascades in Washington and in the Oreon-Washington Coast Ranges the usual oublemakers are red alder, bigleaf maple, nd shrubs such as salmonberry, thimbleerry, and vine maple. In southwest Oregon nd northern California tough evergreen hrubs and weed trees predominate.

n the western slope of the Cascade Range n Oregon, evergreen species such as snowrush, varnishleaf, and mountain whitehorn ceanothus, golden chinkapin, and reenleaf manzanita are common. In Washngton, comparable slopes are occupied by ed alder, bigleaf maple, vine maple, eldererries, and willows.

On the west slope of the Sierra Nevada, forsters deal with evergreen shrubs such as reenleaf manzanita, snowbrush, and mounain whitethorn ceanothus, other manzanias, Sierra evergreen-chinkapin and mounain-mahoganies, bitter cherry, black oak nd bearmat.



Location of brush areas and suggested priorities for reclamation based upon average productivity of commercial forest land.

On the east side of the Sierra Nevada and Cascade Ranges and in the northern Rocky Mountains, brush is commonly evergreen in California and Oregon, but deciduous in Washington and the Rocky Mountains. In northern Rocky Mountain forests, the most troublesome plants are smooth menziesia, snowbrush ceanothus, Rocky Mountain maple, mallow ninebark, creambrush rockspirea, and willows.

This paper provides a good introduction to the problem of brush, methods of control, and research needs.

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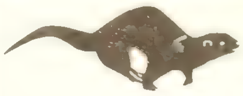
cological Considerations in Brush Control, by H. Gratkowski (176)

A fascinating discussion of the environmenal factors which should be considered when making decisions about using herbicides to ontrol brush: solar radiation, competition or moisture and nutrients, fire, and wildlife.

Take the case of varnishleaf ceanothus. In outhwestern Oregon, studies indicate that arnishleaf (along with Pacific madrone) may act as a nurse crop for young Douglas-irs. The shrub provides shade and reduces urface soil temperatures during the early ritical stages of tree growth. In addition, many species of ceanothus are reported to ix nitrogen in nodules on the roots and add o the available supply of nitrogen in the soil —thereby preparing the way for Douglas-fir o grow.

But, interactions in an ecosystem are never simple. And, in this case, the favorable effect of varnishleaf ceanothus on Douglas-fir appears to be counterbalanced by unfavorable effects as well. Douglas-fir trees shaded by varnishleaf are characteristically slender stemmed and fragile, with narrow open crowns and small amounts of foliage. These stems are deformed as they try to grow upward through the shrubs. Many are broken under snow-laden shrubs in the winter. Height growth is also retarded.

All studies indicate that it would be well to release young Douglas-firs from varnishleaf as soon as the trees are well established on a site. For other brush species and other sites, the story may be very different.



the young volunteers costs about $0.50 in prizes. The time involved in contacting the families, lining up the children, and handing out the rewards is minimal. Both the money and manpower saved can be used for other important duties.

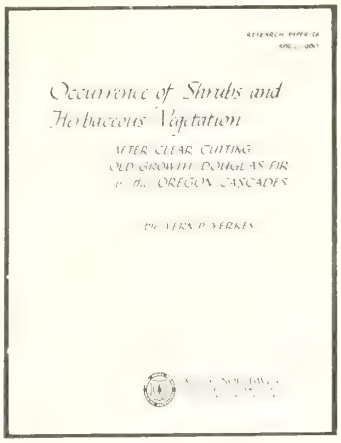
The litter incentive program has some other, not so obvious, benefits. Children who take part in the program leave their camping experience with at least the beginnings of a new environmental awareness. The small, inexpensive rewards, which are readily available at most ranger stations, are a reminder of why they were earned. Some of this awareness also rubs off on both Mom and Pop, who are also part of the litter program.

The use of the litter incentive program has lead to the development of some simple guidelines. According to Clark, the first contact should be with parents. Once the anti-litter campaign is explained, there is no problem in getting children to volunteer. The program seems to work best when the children are shown their incentives before beginning the litter pickup. Young children have been successfully teamed with older ones. These and other points are discussed and demonstrated in ''The Incentive System for Litter Control,'' a 25-minute slide-tape program.

The slide-tape program (including the slides, cassette tape, and script) is available for sale from:

Forestry Media Center
c/o Forestry Business Office
School of Forestry
Oregon State University
Corvallis, Oregon 97331
Phone 503/754-4702
FTS 425-4160

Cost per copy is $45.00. Order by check or purchase order and refer to item No. 747. Make checks payable to: School of Forestry, OSU. Copies may be rented for 3 days for $12.00. National forests in Oregon and Washington can borrow a copy from the Division of State and Private Forestry, Region 6, Portland.



RESEARCH PAPER 14
APRIL 1960

Occurrence of Shrubs and Herbaceous Vegetation
AFTER CLEAR CUTTING
OLD-GROWTH DOUGLAS-FIR
in the OREGON CASCADES

by VERN P. YERKES

Occurrence of Shrubs and Herbaceous Vegetation After Clear Cutting Old-Growth Douglas-fir in the Oregon Cascades, by Vern P. Yerkes (177)

What kinds of plants are likely to invade clearcut areas in the Douglas-fir region following logging? A 1960 study in the H.J. Andrews Experimental Forest (Oregon) documents the plants that came in first and describes the succession pattern that might likely occur throughout much of the western Cascades.

The scientist noted the presence of 104 species and species groups during the 5 years of the study. Of these, 101 were found on north slopes and 65 on south slopes.

Woody species that ''survived'' the logging and remained in the clearcut areas included salal, rhododendron, modest whipplea, twinflower, vine maple, Cascades mahonia, and grapeleaf California dewberry. Woody plants that invaded the site later included willow, blueberry elder, and western thimbleberry.

All of the herbaceous species were classified as invaders and included both annuals (annual epilobiums and Woodland groundsel) and perennials: Western hawkweed, pearly everlasting, western bracken, slender cudweed, thistle, and fireweed.

Allelopathic Potential of Western Bracken, by R.E. Stewart (178)

An allelopathic plant is one that releases organic chemicals which inhibit the growth of other plants. Such is the case with western bracken fern. Allelopathic interactions may explain the relative absence of woody shrubs such as thimbleberry and salmonberry from sites that are dominated by western bracken.

In laboratory studies, water soluble extracts from western bracken reduced germination of thimbleberry and delayed germination of salmonberry. No effect was noted on Douglas-fir.

Brush Problems in Southwestern Oregon, by H. Gratkowski (179)

An excellent summary of the brush problems in southwest Oregon. Gratkowski discusses the geography, history of brushfields and their importance, growth conditions, evaluates the problems associated with brushfields, and suggests a research program. This 1960 paper has long been out of print, but a good forestry library should be able to get copies for loan.

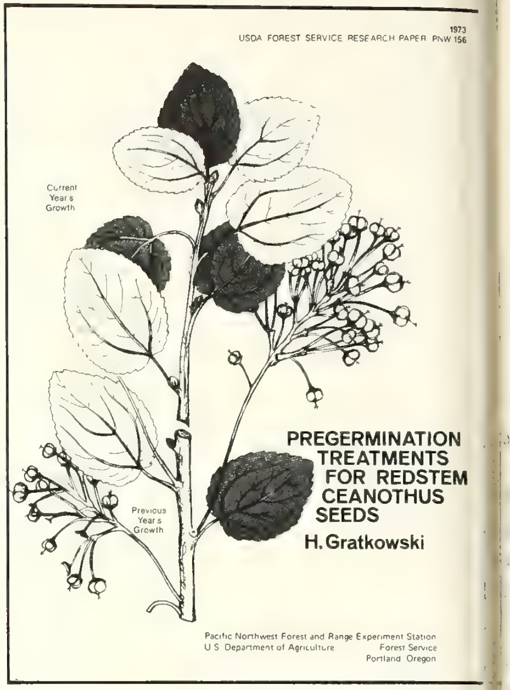
There is general agreement that large brushfields in southwestern Oregon resulted from forest fires. Many have existed for 100 years or more. Once brush has occupied the site, intense competition often excludes forest reproduction. Some brushfields restock naturally, but the process is very slow. Many brush areas remain unstocked for a long time and the site produces only a fraction of its potential timber volume.

Forest survey figures for southwestern Oregon (1951) indicate that there are 315,000 acres of nonstocked burns and old cutovers in this area. Another 865,000 acres are listed as understocked stands of poletimber. Brush probably covers 400,000 acres. An additional 1 million acres have understocked stands of sawtimber, usually with a dense brush understory. Thus, brush control and brushfield reclamation are important land management problems on about one-fourth of the commercial forest land in southwestern Oregon.

New forest survey information for southwest Oregon counties may indicate an even more severe problem at the present time.

In the Umpqua Valley, burning is commonly practiced on cutover forest lands to maintain open pasture.

Hank Gratkowski



1973
USDA FOREST SERVICE RESEARCH PAPER PNW 156

PREGERMINATION
TREATMENTS
FOR REDSTEM
CEANOTHUS
SEEDS
H. Gratkowski

Pacific Northwest Forest and Range Experiment Station
U S Department of Agriculture Forest Service
Portland Oregon

Pregermination Treatments for Redstem Ceanothus Seeds, by H. Gratkowski (180)

Forest land managers don't always want to get rid of brush. What hampers the growth of trees in one place can be food for wildlife and cattle in another.

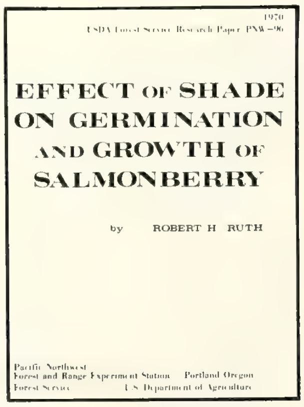
Foresters and wildlife biologists have long been interested in improving winter range for big game. Redstem ceanothus is a good plant for this purpose. Its leaves and twigs are browsed by big game and by cattle and sheep.

In nature, seeds of this plant are induced to germination by wildfires or logging slash fires. For revegetation projects, seeds should be preheated for 10 minutes at 85°C., and then sown during the late fall rainy season. The seeds stratify naturally in the cold, wet soil during winter and germinate in spring.

Happy ceanothus seeding!

Also see:

Origin of Mountain Whitethorn Brushfields on Burns and Cuttings in Pacific Northwest Forests, by H. Gratkowski (181), and *Effect of Shade on Germination and Growth of Salmonberry,* by Robert H. Ruth (182).

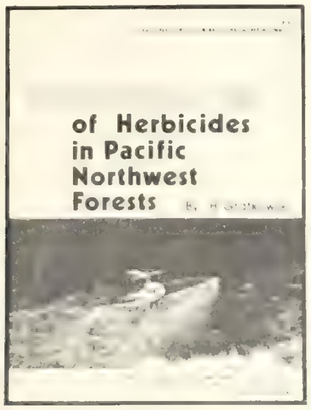


1970
USDA Forest Service Research Paper PNW-96

EFFECT OF SHADE
ON GERMINATION
AND GROWTH OF
SALMONBERRY

by ROBERT H RUTH

Pacific Northwest
Forest and Range Experiment Station Portland Oregon
Forest Service U.S. Department of Agriculture



Use of Herbicides

Use of herbicides as a silvicultural control technique is increasing throughout the Pacific Northwest. Chemicals such as 2,4 D, 2,4,5-T, and picloram are being applied to control woody plants.

H. Gratkowski surveys ten common herbicides and discusses five factors basic to their use. The factors include: the selection of the best herbicide or herbicides for a specific job, determining the amount of herbicide per acre, the use of carriers, the volume of spray to be applied per acre, and the seasons for the application of aerial sprays.

This publication also provides a glossary of common agricultural chemical terms and specific recommendations of herbicidal treatments for many silvicultural brush and weed tree problems.

Silvicultural Use of Herbicides in Pacific Northwest Forests (183). See also *Use of Herbicides on Forest Lands in Southwest Oregon,* also by Gratkowski (184).

Helicopter applying 5 gallons of herbicidal spray per acre; the second 5 gallons per acre will be applied at right angles to the initial lines of flight

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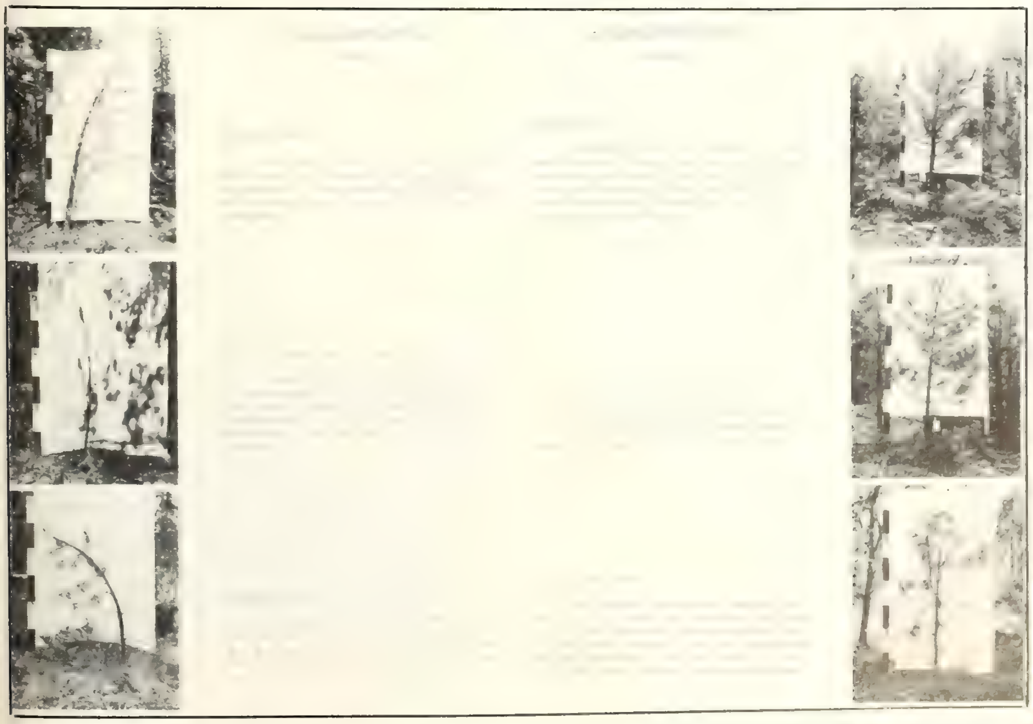
Toxicity of Herbicides on Three Northwestern Conifers, by H. Gratkowski (185)

An early study of the effects of herbicides on three forest tree species common in southwest Oregon—Douglas-fir, ponderosa pine, and sugar pine.

Results indicate that chemical release of Douglas-fir reproduction from brush competition is possible. But release of ponderosa pine and sugar pine is a much bigger problem. Both of these species were damaged more than Douglas-fir by 2,4-D and 2,4,5-T sprays.

Researchers also found that early autumn sprays are far less damaging than midsummer sprays on conifers. And water sprays cause less damage than diesel oil emulsions.

A clever series of photographs in this publication enables the reader to make visual comparisons of the effect each treatment is likely to have on the three species.



Since initial research in 1971, Clark and his colleagues have been working with land managers from a variety of agencies to implement the program. The feedback from both the managers and the public has been very favorable and it appears that the incentive system is well on its way to becoming an established program.

The recipe for success in controlling campground litter is simple. Take the energy and interest of youth, mix it evenly with paper and cans, add a dash of incentive, and top the resulting mixture with a very small portion of your own time and money!

end

FIRE AND ICE

by Thomas Michael Baugh

Mention the word "taiga" to an Alaskan and he immediately thinks of the extensive forests and abundant big game of interior Alaska. The word also brings to mind raging wildfires and hundreds and thousands of acres of ash-covered, smoke-shrouded land.

Each year fires in Alaska burn an average of one million acres. During severe wildfire years, such as 1969, the total may climb as high as four million acres. Long before the advent of man, wildfire was roaring across the taiga, changing the face of the land.

The vegetative landscape viewed by early native people was formed in part by fire. These primitive hunters also introduced the first man-caused fires. The arrival of European colonizers added significantly to the yearly fire score.

Try as he might, however, man can't surpass the fury of nature. Although over 70 percent of the fires in Alaska are now caused by man, they only account for 22 percent of the total acreage burned. The ligntning storms which sweep the state each summer are, by far, the most destructive factor in the Alaska fire picture.

Les Viereck, a scientist at the Institute of Northern Forestry in Fairbanks, says that within the past 200 to 250 years "... a vast majority of interior Alaska has probably burned." This means that over 220 million acres have been blackened by fire in a little over two centuries. In the twentieth century alone over 50 million acres have been burned.

Effects of Herbicides on Some Important Brush Species in Southwestern Oregon, by H. Gratkowski (186)

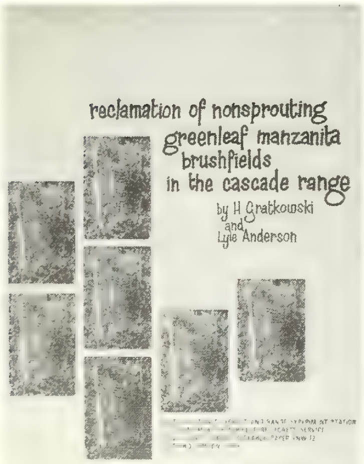
Gratkowski reports results of initial screening tests to determine the effect of six herbicides on the 13 species of brush that are most common in southwest Oregon.

Brush species are divided into three categories:

Highly susceptible: hairy manzanita, hoary manzanita, Howell manzanita, and deerbrush ceanothus.

Moderately susceptible: greenleaf manzanita, snowbrush ceanothus, varnishleaf ceanothus, and mountain whitethorn.

Resistant: golden chinkapin, golden evergreenchinkapin, scrub tanoak, saskatoon serviceberry, and canyon live oak.

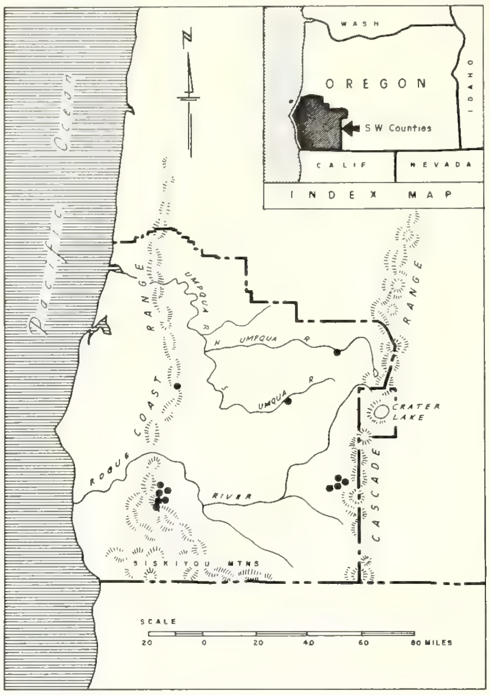

reclamation of nonsprouting greenleaf manzanita brushfields in the cascade range

by H Gratkowski and Lyle Anderson

Reclamation of Nonsprouting Greenleaf Manzanita Brushfields in the Cascade Range, by H. Gratkowski and Lyle Anderson (187)

A nonsprouting form of greenleaf manzanita is of special concern to foresters in southwest Oregon. Dense, relatively pure stands occupy extensive areas of commercial forest land in the southern half of the Cascade Range.

Luckily, this nonsprouting variety can be killed with herbicides at far less cost than the sprouting greenleaf form that is common in the Siskiyou Mountains. So, before you spray, look to see if what you have is the nonsprouting form. Then try the following: 3 pounds of 2,4,-D per acre in a diesel oil-in-water emulsion at a rate of 7 to 8 gallons per acre. For best results, the spray should be applied during the growing season in spring or early summer.

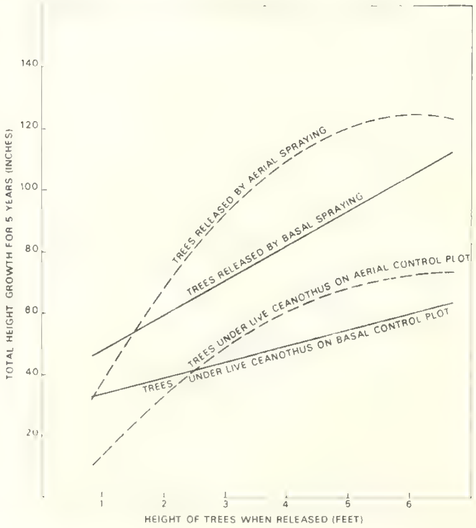


Location of herbicide test areas in southwestern Oregon.

Releasing Douglas-firs from Varnishleaf Ceanothus, by H. Gratkowski and P. Lauterbach (188)

Researchers recommend spraying to release young Douglas-fir trees growing under heavy stands of varnishleaf ceanothus. The trees should be released just as soon as they are well established on the site. According to the western Oregon studies, varnishleaf ceanothus drastically reduces height growth of young Douglas-firs in the understory.

Control of ceanothus is recommended using an aerial application of 2 pounds acid equivalent of low volatile esters of 2,4,5-T per acre in an oil-in-water emulsion to make a spray volume of 8 to 10 gallons per acre. Treatment should be in early spring, just before Douglas-fir buds burst and growth begins.



Repeated Aerial Spraying and Burning to Control Sclerophyllous Brush, by H.J. Gratkowski and J.R. Philbrick (189)

Southwest Oregon brush species must be some of the toughest plants alive. They can resist repeated spraying with herbicides, fire, nibbling by wildlife, and sometimes the best efforts of man to get rid of them.

But with persistence and the right combination of treatments, even the most stubborn chinkapin and live oak can be eliminated.

One application of herbicide is seldom enough to control woody plants such as manzanita, canyon live oak, mountain whitethorn ceanothus, and other sclerophyllous brush species. In fact, it may take an initial application of herbicide, burning, and two more sprayings with herbicides to kill sprouts from the burned shrubs!

In the studies reported here, the cumulative effect of spraying, burning, and respraying was estimated to have reduced the number of live shrubs by half. A second respray further improved the situation so that by 1960—5 years after the study was begun—enough of the brush was killed to allow reforestation.

Greenleaf manzanita sprouted from burls at the soil surface after aerial sprays killed the stems.

Repeated Spraying to Control Southwest Oregon Brush Species, by H. Gratkowski (190)

Most brushfields on forest land in the Pacific Northwest include species that are somewhat resistant to herbicides. Where these species are abundant, repeated treatments will be needed in order to kill a high percentage of the shrubs. Research results indicate that respray treatments on such sites are effective, advisable, and worthwhile. Respray treatments were effective in killing resprouting shrubs, even in species that were somewhat resistant to foliage sprays on healthy, full-crowned, mature shrubs.

Results of studies with 13 brush species are given. The best treatments—including the herbicide and number of sprayings needed—are indicated.

Midsummer Foliage Sprays on Salmonberry and Thimbleberry, by H. Gratkowski (191)

Salmonberry and thimbleberry are major components of most brushfields in the Coast Ranges of Oregon and Washington. They quickly occupy sites after logging or wildfires and combine to make life miserable for foresters who want to get trees growing again.

Amitrole-T is generally considered better than 2,4,5-T for controlling salmonberry during the growing season. But, by midsummer, when the tests reported here were done, better control was achieved with 2,4,5-T. 2,4,5-T worked better on thimbleberry, too, and is less expensive to apply.

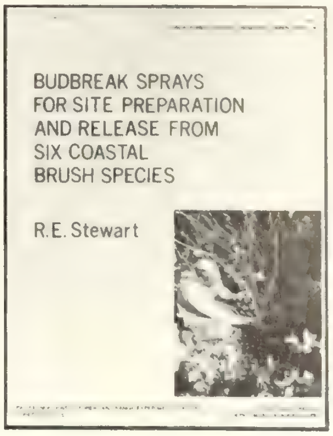
FOLIAGE SPRAYS
For Site Preparation And Release
From Six Coastal Brush Species
R.E. STEWART

Foliage Sprays for Site Preparation and Release from Six Coastal Brush Species, by R.E. Stewart (192)

Herbicidal treatments are recommended for the following brush species common to the Oregon and Washington coasts:
red alder
salmonberry
western thimbleberry
vine maple
California hazel
salal

In general, picloram produced the best control of all six species, and herbicides were more effective when applied in late spring rather than midsummer. Salal gave researchers the most trouble; not even picloram gave adequate control. But the intrepid scientists didn't give up. See the next item for further tests on salal.

Basal sprouts on live salmonberry shrubs were limited in number and size 24 months after spraying with 2,4,5-T.


BUDBREAK SPRAYS
FOR SITE PREPARATION
AND RELEASE FROM
SIX COASTAL
BRUSH SPECIES
R.E. Stewart

Budbreak Sprays for Site Preparation and Release from Six Coastal Brush Species, by R.E. Stewart (193)

Budbreak sprays, or herbicides applied when the buds of the shrubs are just leafing out, can be used to control many coastal brush species. They are often preferred in Douglas fir stands because the conifers are resistant.

Researchers recommend budbreak sprays of 2,4,5-T in diesel oil to control red alder, vine maple, and California hazel.

Budbreak sprays are not recommended for salmonberry and western thimbleberry, but luckily foliage sprays of 2,4,5-T will do the job.

Salal is still a problem. Silvex produced the best results and may work well enough. But researchers still won't recommend a treatment. All they will say at this point is that "sprays containing 2,4,5 -T are promising for control of salal, but additional tests are necessary." That's just another way of saying, "it doesn't work very well."

Repeated Spraying to Control Four Coastal Brush Species, by R.E. Stewart (194)

Four of the major species which compete with timber for growing space in the Coast Ranges of Oregon and Washington can be effectively controlled by using two applications of herbicides.

In a 1970-73 study, researchers tested selected formulations of four herbicides on six of the most common brush species. Resprouting shrubs of salmonberry, western thimbleberry, vine maple, and California hazel were controlled with two sprays of 2,4,5-T. Control was adequate to release conifers or prepare the site for tree planting. A respray of two other chemicals—Amitrole T and Picloram—did not produce better results. Red alder was killed with one application of herbicide, and salal was resistant to all herbicides tested. Maybe now they'll give up!

Scientists at the Institute of Northern Forestry are taking a long, hard look at the natural role of fire in the taiga. Their research points to the fact that much of the ecosystem of interior Alaska is the product of fire. They are questioning the need for the control of all the fires which burn in uninhabited areas and they are suggesting that some wildfires be allowed to burn.

Viereck says that "wildfire has always played an important role in determining the natural vegetation patterns in the Alaska taiga." Modern fire control efforts have caused a "downward trend in the acreage burned in Alaska."

What are the effects of fire on the vegetation and soil of the taiga? Soils throughout much of the interior of the state are permanently frozen. Average temperatures below the freezing point help maintain the condition called "permafrost." During the warmer months the soil thaws to a depth of about 1 to 3 feet. Trees, grasses, and other plants provide an insulating layer which, when combined with a stratum of decomposing plant material, helps keep the permafrost from thawing. In this frozen condition nutrients are locked in the icy soil preventing their use by plants.

This situation changes when the protective layer is removed by wildfire. Viereck and other researchers have found that the heat produced by fire has very little immediate effect on the permafrost. In general, fire moves too rapidly through the trees and plants to cause much thawing of the permafrost. The major cause of thawing is the removal of the insulating layer of plant material.

Without the protective plant canopy, sunlight is able to penetrate to ground level where the soil begins to warm. The dark ash left by the fire absorbs a greater amount of heat which slowly penetrates into the permafrost. It is at this point, following a fire, that the balance of the taiga ecosystem becomes apparent.

As thawing continues deeper into the permafrost, important nutrients are released, nourishing the seeds left undamaged by the blaze. Grasses and other forms of vegetation begin to germinate and grow. Over the years the insulating layer of plant and tree life is replaced, and the permafrost level moves closer to the surface and nearer its prefire levels.

Survival of Ponderosa Pine Seedlings Following Control of Competing Grasses, by R.E. Stewart and T. Beebe (195)

Sometimes foresters want to grow grass along with their trees—as in eastern Oregon or Washington where cattle grazing and timber crops may be compatible.

Other times they may want to get rid of the grass because it competes with trees for water and nutrients. When control is desired, herbicides may be enlisted, as in this study in the Wenatchee National Forest in central Washington.

Researchers were able to increase the survival of ponderosa pine trees by 150 and 700 percent (depending on the soil type) by spraying the grasses with atrazine and dalapon. Grasses were timothy, hard fescue, pinegrass, and orchardgrass. Scalping, pronamide, and terbacil were less effective in controlling the grasses.

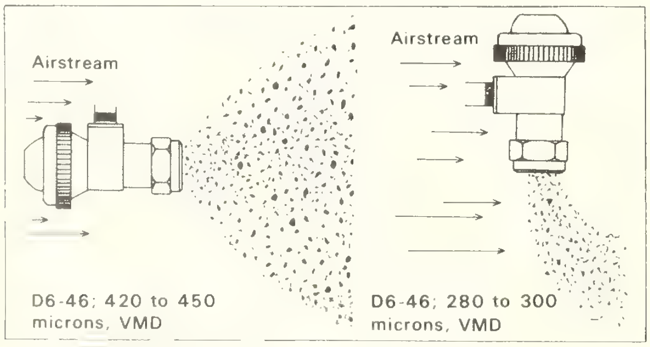
Treatment	Soil type	First year grass control	Second year cover		Second year ponderosa pine survival
			Grass	Forb	
		Percent			
none	Residual	—	68	17	3
	Pumice	—	75	13	39
Scalp	Residual	—	74	12	13
	Pumice	—	71	7	40
Pronamide	Residual	0	70	19	16
	Pumice	0	69	9	23
Terbacil	Residual	28	46	20	21
	Pumice	90	13	16	31
Atrazine	Residual	2	52	13	20
	Pumice	64	27	4	62
Dalapon	Residual	78	24	34	21
	Pumice	73	26	17	58

Initial grass control, present grass cover, and ponderosa pine seedling survival on residual and pumice soils.

Herbicidal Drift Control: Aerial Spray Equipment, Formulations, and Supervision, by H. Gratkowski (196)

Controlling drift of herbicides when spraying on rough, mountainous terrain is necessary in order to reduce environmental contamination and keep the spray within the desired boundaries.

To a great extent, spray drift depends on droplet size. Large drops fall faster and drift less than smaller ones. Other factors that affect drift include the height of the plane or helicopter, flying speed, the characteristics of nozzles and other spray equipment, and the physical properties of the material being sprayed.


Airstream
D6-46; 420 to 450 microns, VMD
Airstream
D6-46; 280 to 300 microns, VMD

Variation in droplet size resulting from change in nozzle orientation on the spray boom.

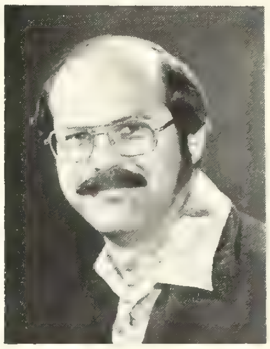
Aerial Spray Adjuvants for Herbicidal Drift Control, by H. Gratkowski and R. Stewart (197)

Preventing drift of herbicides during aerial spray operations is the subject of this 18-page report. One way to control drift is to change the physical properties of the material being sprayed. This can be done by adding adjuvants—chemicals that change the consistency of the material being sprayed.

A number of compounds are now available to reduce drift. These include four types of materials:

a. Invert emulsions
b. Spray thickeners
c. Particulating agents
d. Foaming agents

The advantages and disadvantages of each are discussed.



Ron Stewart

More on Drift Control

Aerial spray tests in western Oregon showed that spray additives in water or oil-in-water emulsion carriers will reduce herbicide drift. Foaming agents and water-soluble polyvinyl polymers were effective additives. However, drift control also reduced swath width and spray coverage which decreased brush and weed tree control with low volatile esters of 2,4,-D and 2,4,5-T.

Foaming agents should be added to water carriers at a rate of 2qt./100 gal. of spray mixture; oil-in-water emulsions require 3 qt./100 gal. Special air-induction nozzles must be used when applying foamed sprays. Use only the nozzles recommended by the manufacturer of the foaming agent.

Spray volumes should be increased to 15 or even 20 gal./A to insure adequate coverage when using drift control additives. Drift control is obtained by applying spray droplets that are larger in diameter, greater in volume, and fewer in number per gallons of spray. With the usual 10 gal./A spray volume, unsprayed areas and strips are almost inevitable even when areas are cross flown or double flown.

See *Aerial Spray Tests of Drift Control Additives for Herbicides in Oil or Oil-in-Water Emulsion Carriers,* by H. Gratkowski and R. Stewart (198).

A funnel for adding and dispersing Vistik.

other

Port-Orford-Cedar—A Poor Risk for Reforestation, by John Hunt and Edward J. Dimock II (199)

The natural range of Port-Orford-cedar is restricted to a rather limited area in Coos, Douglas, Curry, and Josephine Counties in southwestern Oregon and in Del Norte, Humboldt, and Siskiyou Counties in northwestern California.

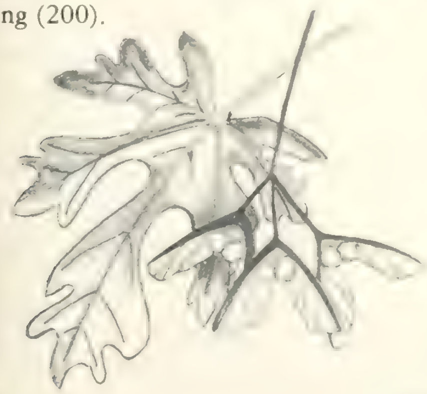
Because of its susceptibility to cold injury and a very destructive root disease, the species should not be used for reforestation outside of its natural range.

Maple Sirup From Bigleaf Maple

What, sirup from the bigleaf maple? Yes, say forest scientists who produced some of the sweet, sticky stuff by tapping trees in the Pacific Northwest.

After doing comparative taste tests, researchers declared the sirup flavorful—but not as strong in typical maple flavor as that made from the eastern sugar maple. Sirup production appears feasible as a hobby and perhaps as a commercial venture.

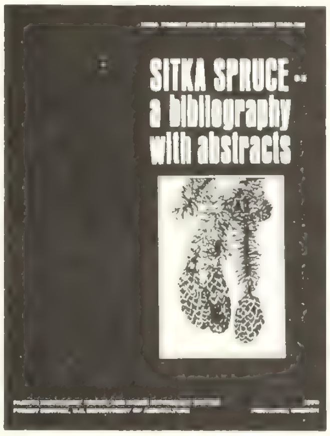
Maple Sirup Production From Bigleaf Maple, by Ruth, Underwood, Smith, and Yang (200).



Investigating Dominance in Douglas-fir Stands, by Kenneth W. Krueger (201)

Why are some trees larger than their neighbors? Are they older? Inherently faster growing? Located on a better microsite? Or do they receive less competition from nearby trees? These possibilities come to mind when observing trees of unequal size in young, even-aged stands of Douglas-fir.

The relative size of individual trees—their "dominance"—was investigated in three young Douglas-fir stands in 1958-59. Findings are reported here.



Sitka Spruce—A Bibliography With Abstracts, by A.S. Harris and Robert H. Ruth (202)

This 251-page bibliography contains references to world literature on Sitka spruce from 1903 to 1967. The report has a list of scientific and common names of tree and plant species that are mentioned. Index is by subject matter and abstracts are given for many references.

Fire has a direct effect on both wildlife numbers and their distribution. For instance, scientists have found that fire improves moose habitat. When the forest cover is burned off, deciduous woody plants such as willow, aspen, and birch, begin to rapidly grow. Moose move into the burned areas in order to browse these plants. Viereck reports that "most of the large concentrations of moose in Alaska, such as those on the Kenai Peninsula, can usually be traced to a large fire, or series of fires in the past."

Efforts at large scale fire control in Alaska began in 1938. Since that time fire control organizations have grown throughout the state, and the modern tools of fire management such as aircraft and dozer tractors have been used.

The Swanson River fire is a good example of man's struggle against fire in interior Alaska. The fire began on August 3, 1969, and by the time it was finally controlled it had consumed 86,000 acres. Over 4,000 firefighters were employed to combat the blaze. They were assisted by 30 helicopters, 79 pumper trucks, and 100 dozer tractors.

It is obvious that all of this manpower and mechanized equipment has a direct affect on the delicate natural systems of the taiga. As an example, researchers point to the fact that erosion and melting of the underlying permafrost is greater along firelines than at any other place in a burned area.

Viereck warns that prolonged periods of fire control will lead to significant changes in the patterns of vegetation in interior Alaska. The mosaic of open, burned areas and stands of trees will be replaced by a more uniform forest with less open areas. This will decrease moose habitat and modify many other wildlife distribution patterns.

Alaska is currently in a period of rapid growth. In the last quarter of this century, the use of Alaska's abundant natural resources, such as timber, may well increase. For this reason fires will continue to be controlled in many areas throughout the interior. Other areas of the taiga, however, will be left open to fire management practices which incorporate the "natural" use of fire. It is logical to assume that future land use planning in Alaska will recognize the pattern of fire and ice which is as ancient as the land itself.

end

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Helicopter Logging: Advantages and Disadvantages Must Be Weighed, by Doyle Burke (1)

Helicopter logging may have advantages where road access is restricted or the use of conventional logging systems is prohibited. Disadvantages related to cost, slash disposal, cull material handling, and post-harvest land management may outweigh the advantages, however. Helicopter logging is especially expensive and therefore may be restricted to the removal of scattered trees or pockets of high-value timber.

Helicopters for Logging—Characteristics, Operation, and Safety Considerations, by P.M. Stevens and Edward H. Clarke (2)

This report presents an overview of factors relevant to the productive and safe use of helicopters for timber harvesting. The load characteristics of approximately fifty helicopters are discussed along with factors such as operating costs, productivity, and safety considerations.

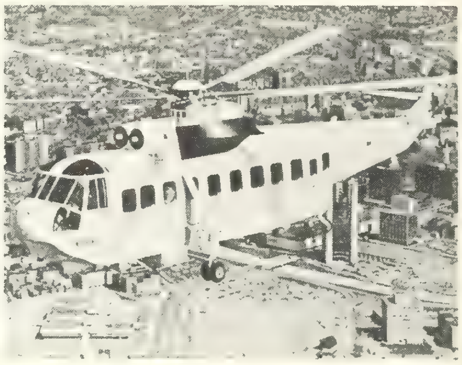
An Analysis of Production and Costs in High-Lead Yarding, by M.E. Tennas, R.H. Ruth, and C.M. Berntsen (3)

Factors influencing production and costs on a high-lead yarding operation in a 100-year-old stand on the Cascade Head Experimental Forest were isolated and analyzed. Industrial engineering techniques and statistical analyses were used to estimate how crew size, haul-in distance, volume per turn, slope, length of yarding road, and number of logs per acre affected production and costs. The influence of these variables is illustrated by a series of curves which demonstrate, for example, that choker-set time increases with increasing distance from the spar tree.

Skyline Tension and Deflection Handbook, by Hilton H. Lysons and Charles N. Mann (4)

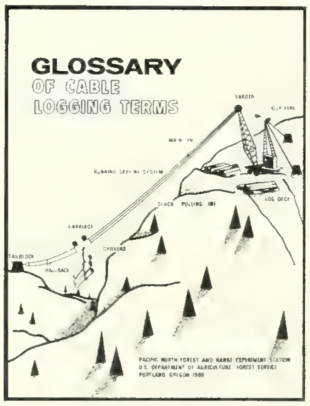
The need for additional information on the capabilities of multispan skylines led to this study of skyline tensions. The report begins with a discussion of the general characteristics of skyline logging systems. It then progresses to a detailed investigation of both single-span and multi-span skylines. Problems, such as the rigging of a 1-5/8-inch-diameter skyline on a convex slope, are posed and then solved by the authors.

Graphs related to load factors and tensions under varying conditions are presented in a general manner to allow the solution of all practical problems.



Soil Surface Conditions Following Skyline Logging, by C.T. Dyrness (5)

The results of a study to compare soil disturbance caused by tractor, high-lead, and skyline logging are reported. Both soil surface disturbance and slash density were recorded at about 1,750 different points on one watershed. The most surprising result of the study is that soil disturbance caused by high-lead and skyline logging were about the same.



GLOSSARY
OF CABLE
LOGGING TERMS

PACIFIC NORTH FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND OREGON 1980

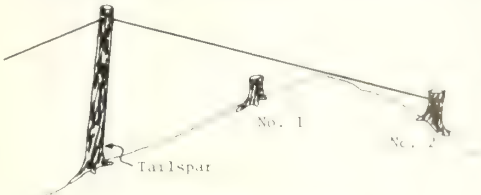
Glossary of Cable Logging Terms, by Pacific Northwest Forest and Range Experiment Station (6)

Did you know that a "top guy" is one of several lines tied to the top of a spar tree, or that a "triple drum" is found on a three-drum yarder? If you had a copy of the *Glossary of Cable Logging Terms* you would have a comprehensive source of dozens of terms used throughout the logging industry.

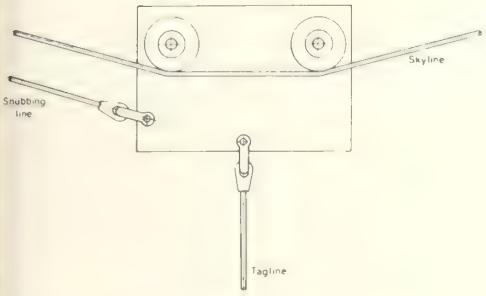
Mechanics of Skyline Anchoring, by Charles O. Campbell (7)

Good anchoring cannot be overemphasized in planning a skyline operation. In the past, there have been many instances when carriages and other equipment have been damaged or destroyed because of anchor failures. Stumps are the most common anchor, and although there are no definite methods of predicting the load-bearing capacity of stumps, a few general observations hold true. The holding power of a stump tends to increase with soil depth and density. Holding power also increases with the square of the stump diameter. A 48 inch stump will hold approximately four times as much as a 24-inch stump.

Methods of rigging stump anchors and calculating load are presented in this paper.



Stump anchor at ridge top



Schematic of snubbed carriage

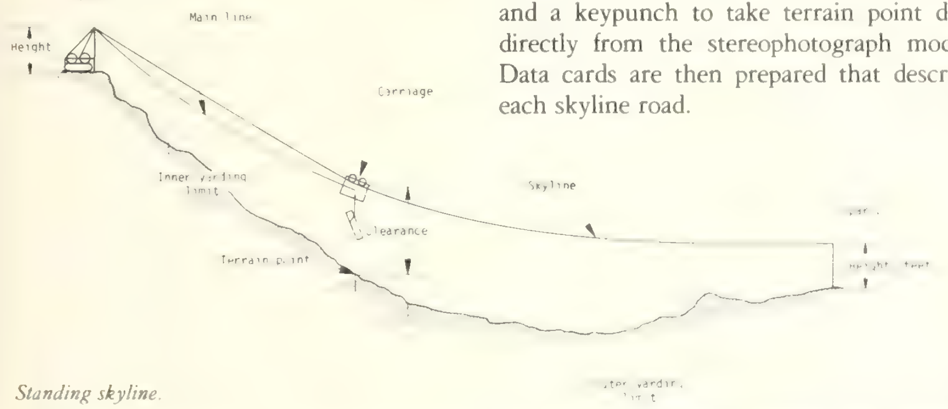
A Technique for the Solution of Skyline Catenary Equations, by Ward W. Carson and Charles N. Mann (8)

The designer of a skyline logging operation must determine the load-carrying capability of his system in order to establish mechanical and economic feasibility. Because of the complexity of the mathematical equations which describe these cable systems, this can be a computationally difficult task. This report proposes an efficient method of computing load-carrying capabilities.

Digitizing Topographic Data for Skyline Design Programs, by W.W. Carson, D.D. Studier, and W.M. Thomas (9)

This research note discusses a procedure for the collection of topographic data from stereophotographs through the use of a Kelsh-type stereoplotter and a digital scaler or digitizer.

First, the skyline designer prepares equipment information and specific road descriptions on photographs. Then the person operating the stereoplotter uses the digitizer and a keypunch to take terrain point data directly from the stereophotograph model. Data cards are then prepared that describe each skyline road.



Standing skyline.

An Analysis of Running Skyline Load Path, by Ward W. Carson and Charles N. Mann (10)

This paper is intended for those who wish to prepare an algorithm to determine the load path of a running skyline. The mathematics of a running skyline design problem are presented. The approach employs assumptions which reduce the complexity of the problem to the point where it can be solved on desk-top computers of limited capacities.

TAMING THE TUSSOCK MOTH
by Thomas Michael Baugh

June 9, 1974, dawned clear in the mountains of eastern Washington and Oregon. As the light of the new day spilled into the dark canyons, the quiet was broken by the pulsing whir of helicopters.

The ungainly airships, carrying long pipes slung from their undercarriages, were part of the largest all-helicopter insect control project ever to take place in the forests of the Pacific Northwest. When their work was finished, a month and a half later, they had sprayed DDT over 426,000 acres of tussock moth-infested forest land.

The control project was the culminating act in a debate and drama which had involved much of the preceding 2 years. The controversy over the use of DDT had raged throughout the United States. Final approval had been given by the Environmental Protection Agency in an attempt to save as much forest as possible from the moth.

At the same time that the helicopters were spreading their loads of insecticide, planning was taking place in the offices of the United States Department of Agriculture in Washington, D.C. Concerned public officials and natural resource managers were in the process of structuring a major scientific effort to investigate the ecological factors related to tussock moth outbreaks and to find their control methods. Companion investigations were also planned for two other forest insects; the gypsy moth in the Northeast and the southern pine beetle in the South.

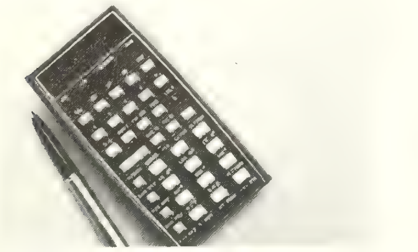
As is true of all native insect pests, the tussock moth is "endemic," meaning always present, but in very low numbers. Occasionally, however, the tussock moth population gets out of balance with its environment and a population explosion occurs. The result can be severe defoliation and death of many trees over thousands of acres. Tussock moth outbreaks occur in the West on the average of about every 7-10 years, although not usually in the same location. For example, another serious outbreak may not occur until about 1980, but not necessarily in the Blue Mountains of Oregon where defoliation was severe in 1972-74.

Running Skyline Design With a Desk-Top Computer/Plotter, by W.W. Carson, D. Studier, and H.H. Lysons (11)

The running skyline system is being used by an increasing number of timber operators for thinning and clearcutting. It is a system of two or more suspended moving lines, generally referred to as main and haulback, that when properly tensioned will provide lift and travel to a suspended load. The desk-top computer approach presented in this paper allows the planner to determine deflection and load path for a specified load.

Determination of Skyline Load Capability with a Programable Pocket Calculator, by W.W. Carson (12)

For planning purposes, logging engineers need tools and methods to determine the load-carrying capability of skyline cable systems. Both computerized and hand computation methods are available for these determinations; however, no approach has been reported that could be programed onto the pocket-size computers available. This paper presents a method that will determine the load capability of a running or standing skyline on a programable pocket-size calculator.



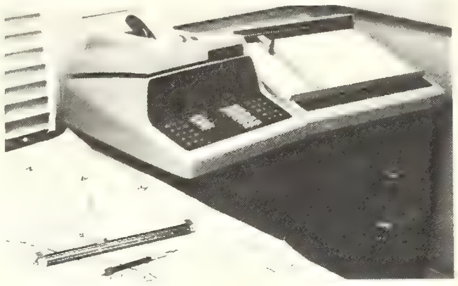
Skyline Logging: An Economical Means of Reducing Environmental Impact of Logging, by Hilton H. Lysons and Roger H. Twito (13)

Present-day skyline logging systems offer many opportunities for substantially reducing environmental impact. These systems can reduce road density and landing area as well as soil and water disturbance. In partial cut situations, skyline systems have performed with little damage to the residual stand and in an economical manner.

A Computer Program for Determining the Load-Carrying Capability of the Running Skyline, by Ward W. Carson and Donald D. Studier (14)

A logging system designer must know what payload a logging system can carry over a given ground profile. A computer program has been designed for this purpose. This program can be used by the timber resource planner for determining the feasibility of a running skyline system. The program was written in standard Fortran IV language for the CDC-6400 machine. It has also been prepared to operate on the CDC-6100.

The authors show how to apply the formulas developed in the previous paper (*Running Skyline Design With a Desk-Top Computer*).



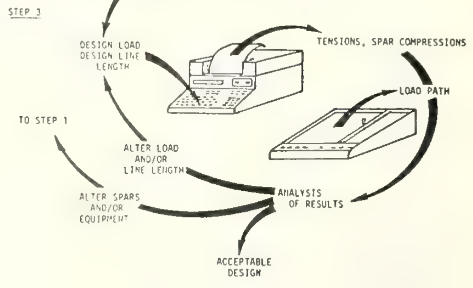
Calculator, printer, and plotter combination.

Skyline Logging Profiles From a Digital Terrain Model, by Doyle Burke (15)

A digital terrain model based on input from improved topographic and orthophoto maps can help to accurately evaluate alternatives for skyline logging operations. A digital terrain model program is available to transcribe data from maps into profile plots. The program has been written in BASIC language for use on the Hewlett-Packard 9800 system. This system includes a digitizer, plotter, cassette memory, and printer.

Skyline Mechanics Simplified, by Ward W. Carson (16)

The introduction of desk-top computer systems has simplified the design of skyline shows. Desk-top systems, with capabilities previously available only with large computers, offer a readily available tool for understanding skyline mechanics. The present generation of desk-top computer systems offers three advantages not available as recently as 5 years ago. These include algebraic, problem-oriented program language, increased memory capacity, and a wider range of support equipment such as digitizers, plotters, and printers.



Desk-top design process.

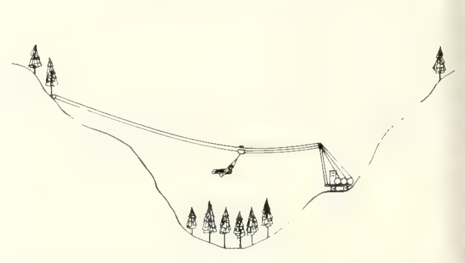
Running Skylines Reduce Access Road Needs, Minimize Harvest Site Impact, by Doyle Burke (17)

A well-planned running skyline system can substantially reduce access road mileage while providing almost unlimited flexibility in meeting timber harvest requirements. The running skyline, one of the most versatile yarding systems ever developed, is designed around the three-line interlocked yarder with tracked or wheeled undercarriage.

Running skylines can be matched to almost any timber harvest situation. They provide for extended yarding up to 2,000 feet. Road spacing can be increased to almost twice that of systems with uphill yarding capability only. Running skylines allow lateral yarding up to 150 feet, reduce average yarding distance, and can be rapidly set up and moved.

New Tools Allow Examination of Skyline Alternatives Speedily, by Doyle Burke (18)

In a summation of the application of desk-top computers to running skylines, logging engineer Doyle Burke says that desk-top calculator systems with digitizers and plotters provide the logging engineer with the means to examine numerous alternatives with speed and accuracy. They allow the engineer to find the best solution rather than just an acceptable solution.



This profile depicts yarding on both sides of a stream, while leaving stream buffer.

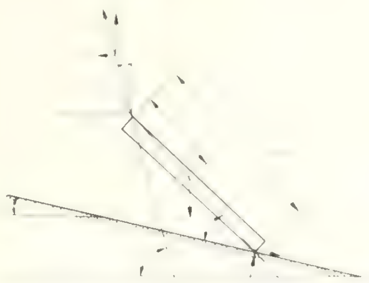
Harvesting Commercial Thinnings on Steep Slopes, by H.H. Lysons (19)

The problem of developing a viable cable system for harvesting commercial thinnings is particularly challenging. This is due to the need to develop a low-cost machine to be economically acceptable, and yet be of the most advanced design to permit thinning of selected trees at a suitable rate with little impact on the residual stand or the environment.

Technology is rapidly approaching the point where major advancements in commercial thinning via cable systems can be anticipated.

nalysis of Running Skyline With Drag, by Ward W. Carson (20)

iost computations for determining the ad-carrying capabilities of running skyline stems are based on the assumption that e log load is suspended in the air or is in ictionless contact with the ground. This is rely the case. This paper presents a mathinatical procedure which successfully odels the forces and displacements that ist in a running skyline configuration with dragging log load. The procedure has been ogramed for desk-top computers and should provide the logging engineer with more realistic estimates of the conditions existing in a running skyline system.



Log skidding geometry

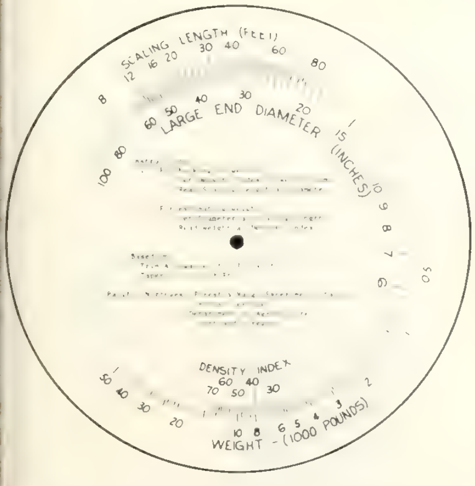
rograms for Skyline Planning, by Ward W. Carson (21)

his publication presents four computer rograms with specific application to skyline arvest unit layout. One program prepares rrain profiles from maps. The other three xpress characteristics of load-carrying skynes.

Method of Estimating Log Weights, by Charles N. Mann and Hilton H. Lysons (22)

he forest industry has long recognized the eed for a practical method of estimating he weight of logs before they are yarded. he need for this type of information has icreased with the development of aerial loging systems which have critical weight re uirements and limitations.

method of estimating pre-yarded log eights is now available. The method uses a actor called a density index. Before log eights are estimated, the local density ndex for a specific species of log is found by neasuring and weighing truckloads of these ogs. The density index is then used to estinate the weight of remaining logs of the ame species before they are yarded. Graphs nd tables for estimating log weight are iven.



Slide rule for estimating log weights.

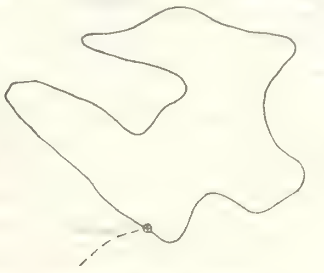
Correction of Average Yarding Distance Factor for Circular Settings, by Hilton H. Lysons and Charles N. Mann (23)

Given the external distance of geometrically-shaped settings a factor is commonly used, in logging cost analysis, to determine the average yarding distance. For circular settings, or segments thereof, the average yarding distance is 2/3 or 0.667 of the external distance. A factor of 0.707 had been used prior to this determination.

Average Yarding Distance on Irregular-Shaped Timber Harvest Settings, by Penn A. Peters and J. Doyle Burke (24)

The trend to natural-shaped cutting units poses new problems in rapidly and accurately determining area and average yarding distance. Easy methods for determining the average yarding distance and area are available for simple shapes such as right triangles, rectangles, and circular arcs. The average yarding distance and area of irregular shapes can be determined by a method known as numerical integration. Unfortunately this involves a time consuming manual computation which makes it impractical for most uses.

A simple and accurate technique for determining the area and average yarding distance of a setting of any shape is now possible through the use of a programmable calculator coupled with a peripheral digitizer. The digitizer transfers the necessary information from a map to the calculator which is programed to compare area and average yarding distance.



Large, irregular-shaped cutting unit.

Just as the interval between outbreaks is somewhat predictable, so is their length. Entomologists have noted striking similarities in the outbreaks which have occurred in the West since 1935. Outbreaks usually follow a distinct 3-year pattern, with the outbreak peaking dramatically during the second year and declining at the end of 3 years. It seems that nature cannot support a population that is out of balance; an equilibrium is eventually sought and reached.

With a native pest such as the tussock moth, there are many natural enemies—including insect parasites, predators, and diseases—which help keep it in check. Exhaustion of the insects' food supply and other environmental factors may also be partly responsible for the decline of outbreaks.

The program expects to develop the capability to detect, evaluate, and suppress outbreaks of the tussock moth by the fall of 1977. This capability will rely heavily on a newly developed chemical sex attractant to detect and evaluate potential tussock moth outbreaks. Several effective, short-residual, chemical pesticides and one or more biological materials are expected to be registered by 1977. In addition, the major effects of these materials on the environment should be known.

Early detection of tussock moth outbreaks is important because of the rapidity with which outbreaks can develop. Through the Tussock Moth Program, an accelerated effort is being made to field test and further develop the sex attractant of the tussock moth so it can be used for prediction as well as detection of outbreaks. Forest land managers could then pinpoint areas where tussock moth populations are building up and apply control measures while infestations are still small.

Two very promising biological control materials are a virus of the tussock moth which often helps bring outbreaks to a halt naturally and Bacillus thuringiensis, *a bacterium which is commercially available and used against the tussock moth in field experiments, are environmentally safe and can be applied as aerial sprays. Development of new, environmentally safe chemical insecticides is a short-term goal of the program. Some of the most promising are Orthene, Dimilin, and Carbaryl.*

Estimating Production of a Skyline Yarding System, by Penn A. Peters (25)

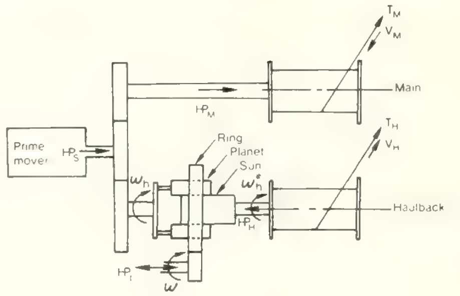
Estimating production of a yarding system is complicated by the effects of yarding distance, harvest unit layout, volume per acre, crew efficiency, terrain, brush, log size, and machine capability. Most current estimation methods depend in part on data obtained from field studies. This is often a time consuming and costly process.

A method of handling this problem has been developed using the concept of a load curve with built-in delay factors. Road changing time is included as a major component and downtime is accounted for by percentage correction.

Typical skyline road.

Understanding Interlock Yarders, by Ward W. Carson and Jens E. Jorgensen (26)

To appreciate the need for interlock devices on a cable logging yarder, one must understand the principle of the interlocking drums. This publication describes the function of the interlocking mechanism focusing on the slipping clutch, planetary interlock, and direct drive interlock systems.



Planetary gear interlock.

A New Approach to Yarding Cost Analysis, by Penn A. Peters (28)

An important part of logging planning is the preparation of yarding cost estimates. Large companies and public agencies often employ time studies and regression analyses to develop mathematical models to estimate logging costs. A new method has been developed to arrive at estimates of logging costs. This method allows the log size frequency to be estimated in advance of yarding. It also provides a load curve applicable to a wide range of terrain and timber conditions.

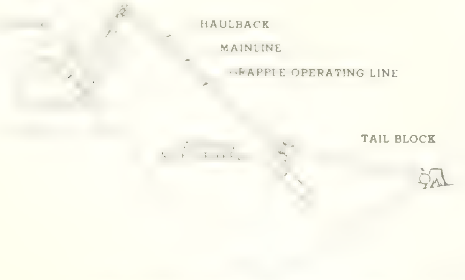
Yarding System Capabilities, by Hilton H. Lysons (29)

Increasing constraints on logging practices makes it important to understand the capabilities of the variety of yarding systems available for logging purposes. Tractors, high lead, standing skylines, running skylines, balloons and helicopters all play a role in the logging picture. Each of these systems, however, can be applied best in specific logging situations. The best yarding system for a particular job is the one that meets performance requirements, in terms of the physical and environmental criteria, at the least cost.

Road and Landing Criteria for Mobile-Crane Yarding Systems, by J. Doyle Burke (27)

Rising logging costs and increased environmental concern have been instrumental in bringing about the trend to mobile-crane, grapple yarding. This system is designed around the three-line running skyline and is characterized by low manpower requirements, increased safety of personnel, reduced average yarding distance, separate loading operation, and decreased soil disturbance. Log size is the most important variable affecting costs.

Roads should be located to take advantage of the yarder's mobility to reduce average yarder distance. They must have adequate width for yarder operation independent of the loader, and should provide for uphill and downhill yarding. Landing areas should be such that logs will not roll or slide and the combined road and landing should provide sufficient room for the loading and trucking operations.



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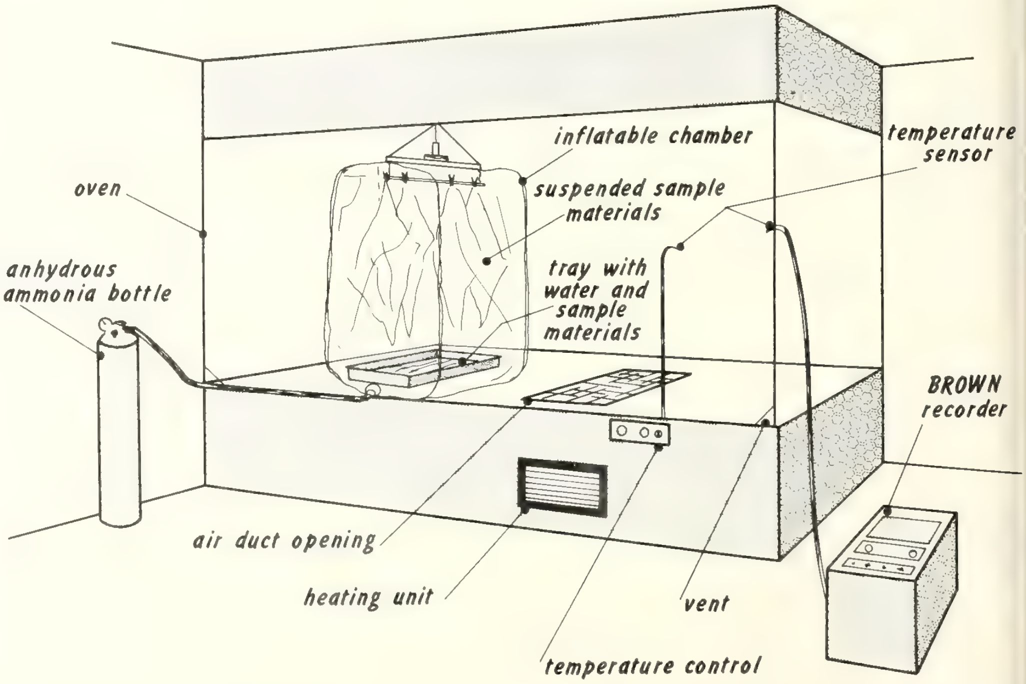
Compatibility of Balloon Fabrics With Ammonia, by Hilton H. Lysons (30)

Ammonia was tested as a possible inflation gas on 18 different balloon materials. Nylon was the only fabric which showed favorable life test characteristics. Neoprene-coated nylon fabric showed no deterioration in either NH_3 gas or NH_4OH after eight weeks of exposure.



Setup for testing compatibility of balloon fabrics with ammonia.

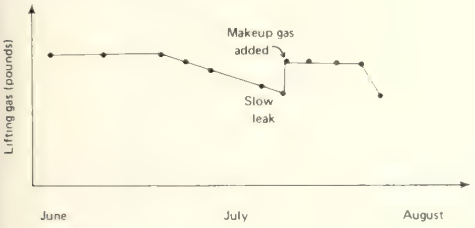
Logging Test of a Single-Hull Balloon, by H.H. Lysons, V.W. Binkley, and C.N. Mann (31)

In 1965, researchers at the Forest Engineering Laboratory in Seattle, Washington, tested a single-hull balloon in a logging situation. As a result, they recommended that balloons be used for downhill yarding where logs can be pulled away from facing slopes and where the long yarding distances available with these systems could substantially reduce roadbuilding costs.

Arrangement of operational equipment for single-hull balloon test.

Gross Static Lifting Capacity of Logging Balloons, by Ward W. Carson and Penn A. Peters (32)

Logging balloons are operated in a variety of atmospheric conditions. The influence of these conditions on the gross static lifting capacity of the balloon can be computed from the fundamental principles of aerostatics and thermodynamics. This research paper discusses factors such as humidity, atmospheric pressure, and temperature as they affect the lift capacity of balloons. Nomographs (charts) are supplied which make the calculation of lift capacity a relatively painless process.



Record of lifting gas stored in balloon.

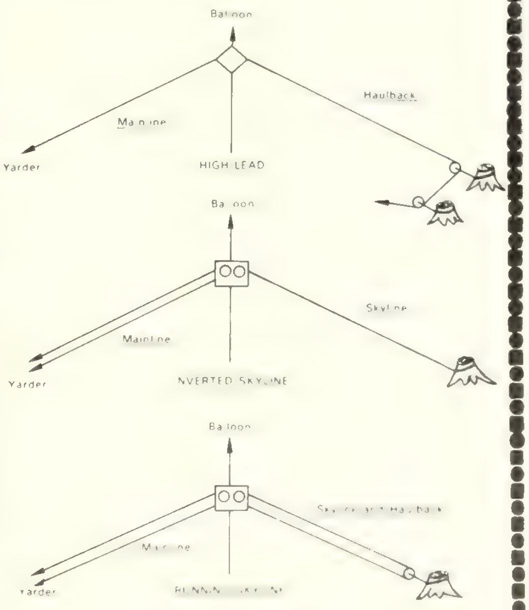
Soil Surface Conditions Following Balloon Logging, by C.T. Dyrness (33)

This is one of a series of studies dealing with soil surface conditions following various forms of logging. Researchers have found that balloon logging caused substantially less soil disturbance than previous studies had shown for tractor, high-lead, and skyline logging methods. In one area, deeply disturbed and compacted soil areas occupied 4.3 percent of the total area, and 15.8 percent of the area was classed as slightly disturbed.

Hilton Lysons

Balloon Logging: A Look At Current Operating Systems, by Penn A. Peters (34)

Balloons are practical for some logging situations. They make it possible to fly logs clear of the ground, and to log convex slopes. Balloons reach up to 5,000 feet and yield a better stumpage return than other aerial methods. On the minus side, failure of balloon fabric and the subsequent loss of expensive helium bother most operators. The greatest environmental and operational hazards are high winds and snow.



Balloon logging rigging systems

Aerodynamic Coefficients of Four Balloon Shapes at High Attack Angles, by P.A. Peters and H.H. Lysons (35)

Since first introduced in the summer of 1963, tethered balloons have been used to yard logs in the Pacific Northwest. Balloons provide a means of harvesting difficult terrain with little impact on the forest environment from access roads or soil disturbance. Knowledge of the aerodynamic characteristics of tethered balloons, as presented in this paper, is necessary for the safe, efficient operation of balloon logging systems.

Extensive field testing is continuing to establish the effectiveness of these materials. Research and development is also required to develop the best aerial application techniques, the minimum dosages needed, the best spray droplet sizes, and to determine environmental effects.

Concurrently, the program is supporting research to develop an understanding of the causes of periodic tussock moth outbreaks. To reduce the need for an extensive detection system, it is important to identify the types of forests most susceptible to outbreaks, and to assemble cost-benefit information to determine what management techniques are most appropriate to prevent outbreaks. The work is essential for development of a pest management system which may reduce the need for chemical pesticides.

The natural factors which promote or inhibit outbreaks are also under investigation. These include factors as diverse as local weather conditions, topography, timber type, and natural enemies of the moth including parasites, predators, and disease organisms.

Many other specialized phases of research and development supplement these studies: for example, research in computer modeling to simulate forests damaged by tussock moth outbreaks; new techniques to sample forests for tussock moths; sociological studies that monitor effects of the outbreaks on recreation and the local economy and health of residents; and determination of impact on wildlife habitat and other non-timber resources.

What of the moth itself? How long will it be around? The Douglas-fir tussock moth is probably as old as the forests. The chances are good that sometime within the next several years moth populations will expand again somewhere in the western United States. After all, the tussock moth has been following its 7- to 10-year cycle of expansion and decline throughout recorded history. The next time this occurs, however, new environmentally sound methods of pest suppression will be available.

end
next "insight" page 109

The Mass Diagram in Timber Access Road Analysis, by Doyle Burke (36)

Mounting pressures on government and private timber managers to reduce the detrimental impact of roads have resulted in a number of modified construction practices. Most notable among these is the end hauling requirement which eliminates indiscriminate sidecasting of surplus excavated materials. These materials often find their way into streams. They also contribute to embankment failures and other forms of mass soil movement.

The use of the mass diagram (a plotted curve which provides sums of earthwork quantities) can help evaluate the impact of end hauling and provides an indication of total volumes of excavation and embankment along roadways. The diagram also indicates accumulative volumes and their locations along a roadway.

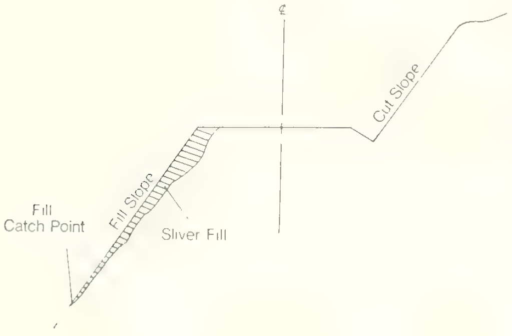


Diagram of road section with sliver fill.

Topometrics: A System for Evaluating Route Alternatives, by Doyle Burke (37)

Topometrics via desk-top computers offers a low-cost, readily available route evaluation system to engineering planners. The system is simple to use, provides for interactive design, and produces graphic and printed results.

The engineering appeal of the system is enhanced because it relies on a proven engineering design process. The designer with professional skills and knowledge is the key, not the computer system. The role of the computer is simple: rapid data manipulation and formatted output. Responsibility for evaluation and decision making rests with the engineer.

A thorough planning effort is possible because the cyclic design process rapidly converges on the best alternative and simultaneously documents results. Costs, safety, and esthetic factors can be more easily evaluated because of the quantitative nature of the results.

Desk-top calculator system with digitizer, plotter, printer, and card reader.

Automated Analysis of Timber Access Road Alternatives, by Doyle Burke (38)

Timber harvest planning and design begins with a thorough analysis of the maps and aerial photographs covering the proposed harvest area. This aspect of the design process can, if properly done, reveal much about the planning area and increase the efficiency of the layout crews in the field. Alternative roads, landings, and settings can be evaluated on paper, and the most suitable combination of these scheduled for field examination.

An analytic system for evaluating timber access road alternatives, using topographic maps and a desk-top calculator, digitizer, and plotter, is now available. The procedure is simple, fast, accurate, and allows maximum interaction and engineering judgment on the part of the designer. This information should be useful to resource managers and of particular interest in planning logging and transportation systems.

Planning Mountain Logging on the North American West Coast, by H.H. Lysons and G.V. Wellburn (39)

Road costs and environmental damage can be minimized by careful planning to reduce road and landing density and minimal earthwork. Lower yarding costs can be achieved by using mechanically efficient systems that have minimal impact on the environment.

The net result of good planning is achievement of desired land management objectives and minimization of total logging costs.

More on Skyline Logging

A lot more information on skyline logging is available as a result of a symposium held in December 1976. Several Experiment Station people gave talks at that meeting. The following papers are available by writing to Publications Distribution (see address on page 131):

"Where and How Skylines Work Best," by Ward W. Carson

Skylines work where and when they have landings, anchors, and payload capability. The physical variables influencing these requirements most strongly are topography, timber size, road location, and yarding equipment. The relationship between these requirements and variables, which must be considered by the logging systems planner, is discussed.

"Why Log With Skylines," by Hilton H. Lysons

The relative costs of roading and yarding are reversing the trend of 30 years ago. Road costs are now rising faster than yarding costs. This is prompting land managers to look to advanced skyline systems to reduce logging costs and environmental impact.

"Automated Yarding Cost Estimation," by Doyle Burke

Yarding cost estimation is of prime importance in logging planning, but is extremely difficult to accomplish manually when several yarding alternatives are being considered, especially within reasonable time limits. A method of automated yarding cost estimation has been implemented on a desk-top computer system using a deterministic approach.

"Why Running Skylines and Interlock Yarders?", by Charles N. Mann

Running skyline systems are receiving increasing acceptance as a method to satisfy current logging needs. These systems are operated most effectively by interlock yarders. This paper presents: the basic running skyline system; an example of power required by various methods of line tensioning to explain the need for interlock; and the suitability of this system to satisfy current logging needs.

Copies of the 196-page *Proceedings, Skyline Logging Symposium* are available for $6.00 each from Centre for Continuing Education, University of British Columbia, Vancouver, B.C. V6T 1W5.

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insect and disease

See also:
Silviculture
Watershed
Timber Quality
Alaska

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forest insects

insect pests

Forest Pest Leaflets

General information about forest insects is available in a series called *Forest Pest Leaflets,* published by the Forest Service, USDA. These short articles are full of basic and useful information. Generally, they give a description of the biology and ecology of the insect and discuss the range of the insect pest, its host trees, life history, and biological, silvicultural, and chemical control methods.

Following is a partial list of *Forest Pest Leaflets* (1), including some of the more important forest pests. Order from the Experiment Station or from U.S. Forest Service, Region 6, Insect and Disease Control, P.O. Box 3623, Portland, Oregon 97208.

The Heart Rots of Redwood, #25
Heart Rots of Incense-Cedar, #30
Pine Root Collar Weevil, #39
Elytroderma Disease of Ponderosa Pine, #42
Sitka-Spruce Weevil, #47
Laminated Root Rot of Douglas-fir, #48
Western Spruce Budworm, #53
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The Pandora Moth, #114
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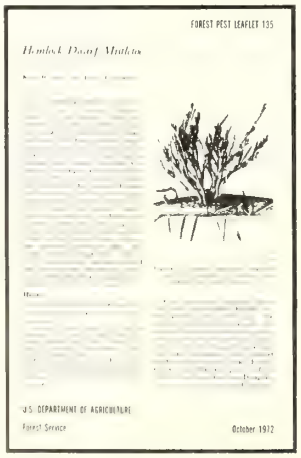
Balsam Woolly Aphid, #118
Western Tent Caterpillar, #119
Pine Engraver, *Ips pini,* in the Western States, #122
The Spruce Beetle, #127
Phytophthora Root Rot of Port-Orford-Cedar, #131
Hemlock Dwarf Mistletoe, #135
The Large Aspen Tortrix, #139



FOREST PEST LEAFLET 135

Hemlock Dwarf Mistletoe

U.S. DEPARTMENT OF AGRICULTURE
Forest Service
October 1972

balsam woolly aphid

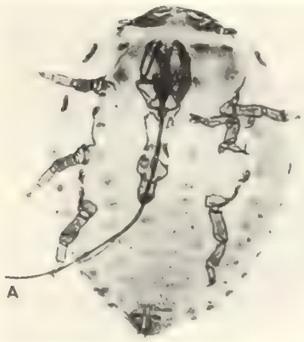
Infestation Characteristics of the Balsam Wooly Aphid in the Pacific Northwest, by Russel G. Mitchell (2)

The balsam woolly aphid is one of the most inconspicuous insect pests in the woods. Because the aphid itself is so tiny and the damage accumulates over a period of years, the insect's presence often goes unnoticed. However, the aphid's size and method of attack is not a measure of its importance. In the Pacific Northwest, the aphid has demonstrated considerable ability to kill and damage three species of our native true firs.

Between 1950 and 1957, more than a billion and a half board feet of commercial-sized sawtimber was killed or seriously weakened in a 400,000-acre area in southwestern Washington. Additional unmeasured damage has occurred since.

Early recognition of damage caused by the balsam woolly aphid can result in considerable savings of timber. Stands suffering the greatest damage should be scheduled for early logging. This paper will aid the forester and landowner by describing (a) some distinguishing characteristics of the aphid and its damage and (b) the nature of balsam woolly aphid infestations as related to its three principal hosts in Oregon and Washington—Pacific silver fir, subalpine fir, and grand fir. Information is also presented on the susceptibility of 15 other species of firs —exotic and native—growing in the Pacific Northwest.

Gouting by balsam woolly aphids settling only around the buds and annual nodes. Typical on trees with smooth internodal bark such as grand fir.



Greatly enlarged ventral view of an adult balsam woolly aphid. The threadlike mouthparts (A), through which food is taken and toxin injected into the host, are about twice as long as shown here.

Foreign Predator Introductions for Control of the Balsam Woolly Aphid in the Pacific Northwest, by R.G. Mitchell and K.H. Wright (3)

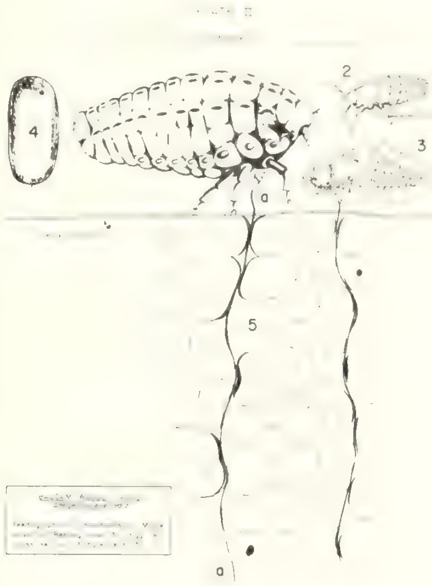
The balsam woolly aphid causes major damage to true fir forests in North America. A program was begun (now discontinued) in 1957 to control the pest in Oregon and Washington by introducing insect predators.

Twenty-three species have been introduced from seven countries throughout the world. They include 15 species of beetles, 4 of flies, 3 of lacewings, and 1 bug. Three species of flies and two species of beetles are successfully established. They prey on the aphid but so far have not sufficiently reduced populations to prevent tree killing. The aphid problem is expected to decrease as the present virgin old forests are converted, under management, to less susceptible young forests. Aphid predators may become relatively more effective under such forest conditions.

The Balsam Woolly Aphid Problem in Oregon and Washington, by Norman E. Johnson and Kenneth H. Wright (4)

This is a report (1957) on an outbreak of balsam woolly aphid in true firs of Oregon and Washington. A 1956 aerial survey showed slightly more than 200,000 acres infested in southern Washington. In Oregon, approximately 150,000 acres were attacked.

The paper describes: 1) the seriousness of the problem, 2) what is being done and what should be done about it, and 3) the insect and its habits.

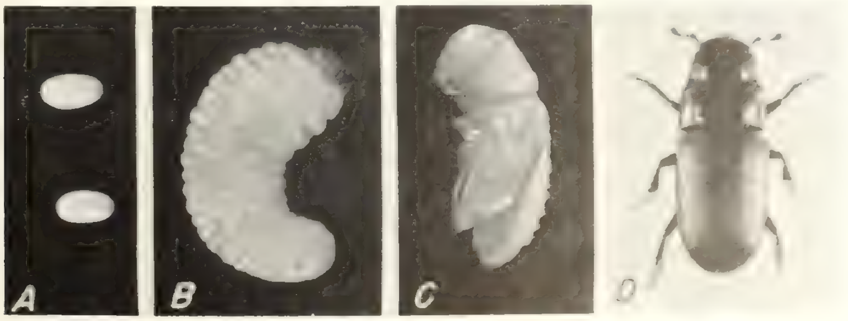


bark beetles in pine trees

The Western Pine Beetle, A Serious Enemy of Ponderosa Pine, by John M. Whiteside (5)

In a format similar to the forest pest leaflets, this report discusses the western pine beetle: the beetle itself, its importance, work and habits, and control methods. The western pine beetle is the most destructive insect enemy of ponderosa pine in the virgin pine forests of California, Oregon, Washington, Idaho, western Montana, and British Columbia. In the United States during the period 1921-45, this beetle, no larger than a grain of rice, killed approximately 2 million trees, or 1 billion board feet of timber, every year. This destruction represents a gross loss of nearly 25 billion board feet of timber, worth 100 million dollars on the stump.

Beetle-killed trees deteriorate rapidly and soon become a total loss to the lumberman. Most of these trees are left in the forest as snags where they fall or rot on the forest floor. Trees thus damaged are also an ever present fire hazard in pine-growing regions.



The four stages of the western pine beetle: A, eggs; B, larvae; C, pupa; D, adult

BURNING WITH RESPECT

by Dorothy Bergstrom

"There hasn't been a fire that we know of in this stand since 1902. But sooner or later another fire will start in the accumulated dead wood and duff. We want to burn now so we can control what happens."

Frank Lehto, a Forest Service fire specialist, was briefing 53 trainees in a workshop on prescribed burning on their final field exercise, an operational burn in a ponderosa pine forest.

After 3 days of training, the students had a far better understanding of the interrelationship of the various elements of an ecosystem. They understood that fire prescribed for any single purpose has complex effects on all parts of the ecosystem. Those effects last a long time and are not reversible. Mistakes can be serious.

With the trainees were two men who had organized and conducted the workshop: John Dell is a fuels management specialist with the Forest Service's Pacific Northwest Region in Portland, Oregon. Robert Martin is a project leader for Silviculture of Interior Forest Types, a research unit of the PNW Station at Bend, Oregon. Martin was formerly an instructor in fire science at the University of Washington. Dell had recently taken a four-week training course in prescribed burning in Region 8 which included operational burns in the South.

Dell and Martin had enlisted a faculty of specialists in botany, ecology, wildlife, meteorology, and prescribed burning, who had been with the students for three days, giving talks, conducting field exercises, demonstrating, explaining, even exhorting. Ecologist Fred Hall had been emphatic: "When someone asks about the effects of burning, you have to ask where and in what plant community. It is vital to consult the local experts in range, wildlife, plants, and soils to find out ahead of time what will happen if a particular site is burned."

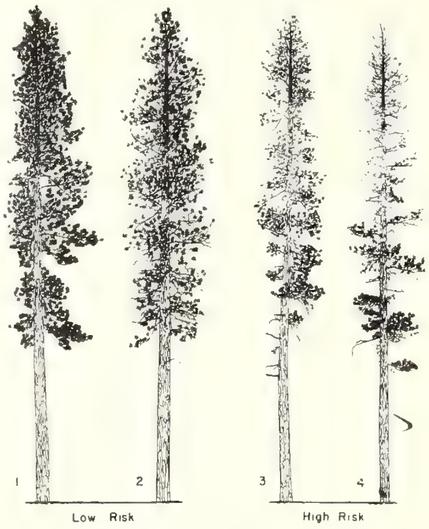
This first workshop in the Pacific Northwest to include field experience in prescribed burning under a timber canopy, brought together employees of several agencies: the Forest Service, the Bureau of Indian Affairs, State Forestry Departments, the National Parks, and a Canadian forestry organization. Most of the students had been trained previously to put out fires. Now they were learning how to use fire safely to achieve specific management objectives.

Biology and Control of the Western Pine Beetle, by J.M. Miller and F.P. Keen (6)

A 381-page book that is a summary of the first 50 years of research on biology and control of the western pine beetle. Published by USDA in 1960, the text is a reference for research workers and for fieldmen concerned with surveys, the appraisal of infestations, and control.

Investigations of the biology and control of the beetle began in 1900. The insect has been the subject of more intensive study during the past 50 years (1910-60) than any other western forest insect.

The pine beetle, of course, was not a problem before the advent of the lumber industry: "Then, as the realization developed that the supply of virgin pine stumpage was limited and that the beetle was hastening exhaustion of the old stands, the western pine beetle became a problem of great importance. The beetle upset logging programs and shortened the life of sawmill communities because it often became active in the woods before loggers reached the timber. It killed the very trees that the lumberman preferred to cut and mill into high quality lumber. Its work earned it the epithet 'The Pine Beetle Logging Company.'"



Degrees of risk in ponderosa pine.

Mountain Pine Beetle in Ponderosa Pine, by Charles Sartwell and Robert E. Stevens (7)

Mountain pine beetle is the major insect enemy of second-growth ponderosa pine in many interior areas of the western United States. Severe tree killing occurs predominantly in dense stands where competition has substantially slowed growth of even the dominant trees. Experiments were begun in the 1960's to determine if beetle outbreaks can be prevented by silvicultural thinning. Early results indicate that thinning of dense stands deserves major emphasis in efforts to minimize this pest problem.

See also a paper on *Thinning Ponderosa Pine to Prevent Outbreaks of Mountain Pine Beetle,* by Charles Sartwell (8), and a report by Keen and Salman, *Progress in Pine Beetle Control Through Tree Selection* (9).

Table 1. Cumulative mortality and net growth 5 years after thinning.

Thinning treatment	Stand density 1967	1972	Mortality M.p.b.[1]	Ips[2]	Other	Total	Net growth
	Stem basal area, sq. ft./acre						
Unthinned	173.2	152.5	11.8	4.0	5.2	21.0	−20.7
12 × 12 ft	116.8	113.5	3.2	2.3	0.5	6.0	−3.3
15 × 15 ft	85.8	89.0	0.2	0.0	0.3	0.5	3.2
18 × 18 ft	61.8	64.8	0.0	0.5	0.3	0.8	3.0
21 × 21 ft	35.0	37.2	0.0	0.0	0.8	0.8	2.2

[1] *Mountain pine beetle.*
[2] *Pine engraver* (Ips pini *(Say)).*

Silvicultural and Direct Control of Mountain Pine Beetle in Second-Growth Ponderosa Pine, by Charles Sartwell and Robert E. Dolph, Jr. (10)

In the Northwest, the mountain pine beetle, *Dendroctonus ponderosae,* is a major pest of second-growth ponderosa pine. Beetle-killed trees characteristically have grown very slowly for more than 10 years prior to being attacked, indicating that low tree vigor, due to intensive between-tree competition, underlies the occurrence of beetle outbreaks. This suggests that silvicultural thinning may be appropriate in prevention of such beetle infestations. This paper describes results obtained after instituting silvicultural thinning of an area located in the Sumpter Valley, about 15 miles southwest of Baker, Oregon.

In the first 5 years after treatment, thinning reduced killing of ponderosa pole-timber by the mountain pine beetle by more than 90 percent and led to positive net stand growth. The felling and burning of infested trees also substantially reduced tree mortality caused by the beetle, but the treated stand declined in the post-treatment period due to damage by other agents. It was found that the practical effect of direct control, in combination with thinning, was no greater than that obtained by thinning alone.

Charles Sartwell

bark beetles in douglas-fir

Douglas-fir Beetle, *Dendroctonus pseudotsugae* Hopk., by K.H. Wright and R.R. Lejeune (11)

The Douglas-fir beetle is the most destructive insect enemy of sawtimber-size Douglas-fir; severe tree-killing has been recorded throughout the range of the host tree. Some 3 billion board feet of sawtimber were killed in western Oregon and Washington from 1951 to 1954 and more than 400 million feet in the northern Rocky Mountains of the United States in 1952.

Outbreaks in the inland regions differ from those in coastal areas. Those in the interior often last many years and may not decline until essentially all trees of susceptible size (usually over 10 inches in diameter) in the stand or drainage are killed. In some areas, however, the outbreaks tend to subside after a few years. Outbreaks appear to be closely related to stand conditions such as overmaturity and overstocking, and to climatic conditions such as drought.

In the coastal areas, outbreaks usually are of short duration. Here, beetle populations typically build up following major stand disturbances such as blowdown and firekill, spread to green trees, kill large volumes of timber, and then decline rapidly, apparently because of the natural resistance of the host.

This paper, really a chapter in a book, is much like the *Forest Pest Leaflet* series. It discusses distribution, hosts and damage, life history, control measures, and gives selected references.

Fire and Insects in the Douglas-fir Region, by R.L. Furniss (12)

An older paper (1941) that discusses the use of prescribed fire as a control for the Douglas-fir bark beetle in the Pacific Northwest.

It was once widely thought that understory trees and brush were a harboring ground for insects that occasionally would reach epidemic proportions and spread out to kill forest trees! With his usual wit and clarity, Furniss describes the problem:

"Some, considering the understory trees and other vegetation that have developed since concerted efforts have been made to keep fire out of the woods, have concluded that in such cover is a likely place for pest of all kinds to thrive. It is evident to anyone who will observe that there are all kinds of leaping and crawling insects everywhere upon the forest floor. What then would be nore logical than that this multitude of inects should periodically come forth and find he forest trees to their liking? If that is vhat takes place, solution seems simple and lirect. Burn the brush!''

urniss goes on to describe the habits of the Douglas-fir beetle and to pooh pooh the vhole idea of prescribed fire as a cure for he bark beetle problem. Rather, he says, ire prevention is the solution:

'In conclusion, it can be stated that Douglas-fir in western Oregon is normally esistant to insect attacks. Occasionally as a esult of unusual circumstances, an outreak of the Douglas-fir beetle may develop nd for a year or two cause extensive lamage. The best way to prevent a large art of these outbreaks is to prevent the arge forest fires that provide much of the reeding material necessary for the beetles o attain sufficient numbers to attack and ill green trees.''

Ken Wright

The Deterioration of Beetle-Killed Douglas-fir in Western Oregon and Washington, by K.H. Wright and G.M. Harvey (13)

The Douglas-fir beetle sporadically kills large volumes of Douglas-fir sawtimber in western Oregon and Washington. Salvage of dead timber before it deteriorates is often a major problem for forest-land owners and managers. A study was started in 1952 to determine how fast beetle-killed trees deteriorate, the factors influencing the rate of deterioration, and the causal agents. Highlights of the results are:

- Volume of wood deteriorated increases steadily with time.
- Wood deterioration the first year following death is minor, but stain and pinhole borers reduce quality for some uses. After 3 years, the high-value sapwood is extensively deteriorated. By 5 years, there is significant decay penetration of the heartwood. Deterioration is slower in the heartwood, but by 9 years the typical beetle-killed tree is a broken snag with only a sound core remaining in the lower half of the bole. After 11 years, deterioration is usually complete except for the butt-log of the largest trees.
- Rate of deterioration is strongly related to age and size of tree and, to a lesser degree, to locality.
- Timber cruisers can use external tree characteristics to estimate time since death and the attendant amount of deterioration.
- The red belt fungus (*Fomes pinicola*) is by far the most imporant agent causing deterioration.
- Felling breakage is related to time since death and size of tree—when expressed in terms of total number of breaks or height of the first break.
- When established logging priorities are for beetle-killed timber, maximum value will be recovered if consideration is given to: age and size of the timber, locality differences in deterioration rate, accessibility of the timber, topography as it affects felling breakage, products to be manufactured, and changing utilization standards.

Field procedure [illegible]

Lehto talked about the tracts the students were about to burn on his district—the Crescent Ranger District of the Deschutes National Forest in Oregon. ''Besides reducing the accumulated fuel, we want to discourage pine reproduction. The overstory stand is dense enough and still growing. We'd also like to stimulate the growth of snowbrush and bitterbrush to bring in more wildlife. We decided on burning instead of machine piling and burning to avoid damage to the pumice soil. As you know, burning in piles creates intense heat, and vehicles compact the soil.''

Setting objectives for the stand and deciding how to achieve them were steps the trainees themselves would take in the future. Today they were conducting a burn to achieve the objectives of the District and at the same time gaining practical experience. The trainees had been divided into four teams, each led by an instructor trained in prescribed burning. The day before, they had practiced on 2- and 3-acre burns. Today they were to plan and conduct burns of 34 to 68 acres.

The District had made most of the preparations. Vehicles and equipment were in place. Men were standing by to control flare-ups and mop up afterward. Firelanes had been plowed around the plots to be burned. Snags to be saved for wildlife had been marked and sprayed with fire retardant. Local residents had been notified the burn was to take place, an important step because most people in central Oregon still expect the Forest Service to put out fires, not start them.

Since this was an operational burn on his District, Lehto gave instructions about equipment and safety. Cars would be parked facing downhill with keys in them. Cars moving would have lights on. Passengers were to get out and walk through thick smoke. All tools were to be returned to the road.

Part of the students' experience was to identify the vegetation and predict its response to fire. Len Volland, range ecologist, explained, ''There are five plant communities here, and you will find the four plots to be burned are not all the same. There is a strong relationship to slope. As you climb up you will see more manzanita.''

A 10-Year Study of Mortality in a Douglas-fir Sawtimber Stand in Coos and Douglas Counties, Oregon, by K.H. Wright and P.G. Lauterbach (14)

In 1945, a growth and inventory cruise of the Millicoma Forest in Coos and Douglas Counties, Oregon, disclosed that mortality was approximately equal to growth. Follow-up studies were made from 1946 through 1955 to determine causes, amounts, and trends of the mortality. The more important findings of these studies are reported in this publication.

Insects, particularly the Douglas-fir beetle, were the most important cause of tree-killing during the 10 years, accounting for 59 percent of the total mortality. Windthrow and windbreak were next in importance, amounting to 38 percent. Disease, particularly root rot, was also an important factor. Other less important causes of mortality were suppression, mechanical injury, lightning, and ''unknown.''

Recommendations to forest-land managers, based on findings of the Millicoma and related studies, include the following: (a) Strong efforts should be made to salvage killed trees, (b) recently developed survey methods of detection and evaluation should be used to expedite salvage, (c) logging plans should be adjusted for maximum recovery of dead material, (d) more timber access roads should be built to allow prompt pickup of killed trees, (e) small-scale logging equipment should be developed to handle salvage, and (f) cutting budgets should be stepped up when mortality of catastrophic proportions occurs.

Estimating Beetle-Killed Douglas-fir by Aerial Photo and Field Plots, by J.F. Wear, R.B. Pope, and P.G. Lauterbach (15)

Color panchromatic aerial photographs are a reliable method for estimating epidemic tree killing by the Douglas-fir beetle. Color photographs are better than black and white. Sequential color photography taken annually may be used to record the course of an epidemic. By regression sampling, taking a large number of inexpensive photo plots, and ground checking a small number of expensive field plots, a survey of equal accuracy is obtained at less cost than by field survey only. A procedure is outlined for conducting aerial photographic surveys of Douglas-fir beetle epidemics.

Sex Attractants of Bark Beetles

The Douglas-fir beetle infests Douglas-fir throughout much of that tree's range in western United States and British Columbia. It characteristically breeds to epidemic numbers in windthrown or otherwise damaged trees. The resulting progeny sometimes kill vast numbers of live trees. Thinning, harvesting, and removal of susceptible trees are the most effective and economical means of preventing a build-up of damaging populations. However, where susceptible trees are inaccessible or esthetic or other values preclude such management actions, other means of preventing damage or of suppressing beetle populations may be needed. The natural pheromones of the species are being tested to determine whether or not they can fill this need.

In this study, the pheromone MCH (chemically, 3-methyl-2-cyclohexen-1-one) was deployed at three rates and tree spacings around attractive felled trees. The chemical was very effective as an attractant and reduced beetle attacks by 96 percent at one level and 91 percent at the other. But researchers indicate that the attractant is still only a potential control strategy, and that more practical and effective formulations must be developed.

See *Effectiveness of the Douglas-fir Beetle Antiaggregative Pheromone Methylcyclohexenone at Three Concentrations and Spacings Around Felled Host Trees,* by Furniss, Daterman, Kline, McGregor, Trostle, Pettinger, and Rudinsky (16).

Several other reports have been published on bark beetles and sex attractants. See also those lised under (17) in the bibliography.

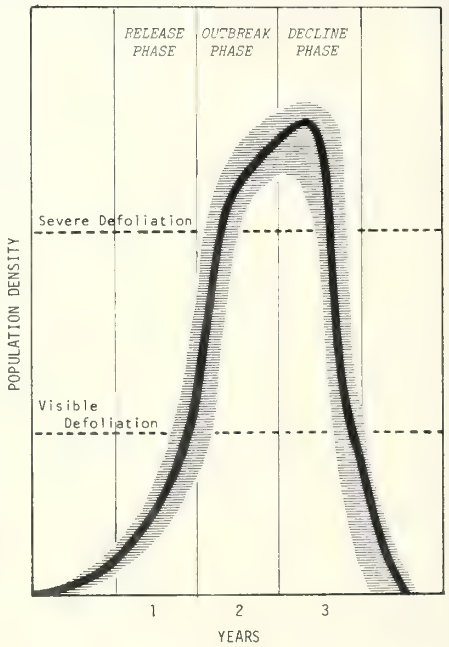
Pheromone dispensers around attractive trees: A, 1X treatment; B, 100X treatment; and C, mounted on stakes 10 feet apart.

douglas-fir tussock moth

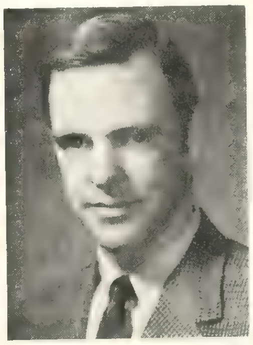
Major Outbreaks of the Douglas-fir Tussock Moth in Oregon and California, by Boyd E. Wickman, Richard R. Mason and C.G. Thompson (18)

Case histories of five tussock moth outbreaks that occurred in California and Oregon between 1935 and 1965 are discussed. Information is given on the size and duration of the outbreaks, the presence of natural control agents and the damage caused. Most of the outbreaks were eventually treated with DDT. However, enough information was available from untreated portions to show the probable trend of natural events in the absence of direct control.

All infestations followed a 3-year cycle with inconspicuous to minimal defoliation the first year, severe foliage loss the second year, and ultimate collapse of the population by the end of the third year. The most severe tree damage occurred in the second year. Additional loss of foliage before population collapse in the third year was usually of minor importance in terms of total impact. Although other natural factors were involved, a virus disease appeared to be the principal cause of insect mortality during collapse.



Hypothetical model of an outbreak cycle of the Douglas-fir tussock moth.



Boyd Wickman

Decay in White Fir Top-Killed by Douglas-fir Tussock Moth, by Boyd E. Wickman and Robert F. Scharpf (19)

One of the earliest recorded and studied outbreaks of Douglas-fir tussock moth on white fir occurred at Mammoth Lakes, California, from 1934 to 1938. In 1937, a 5-acre plot was established there to study the immediate effects of defoliation.

New studies were begun in 1970 when a timber sale, which included the study plot, offered an opportunity to determine if heart rots were a significant cause of defect in white fir trees 33 years after top killing. This was done by dissecting the tops of trees felled during logging. Results were compared with white fir in a nearby logged area where defoliation had not occurred.

Investigations found old top damage and a condition known as wetwood in the insect damaged area. Few decay organisms were found, however. The researchers conclude that in east-side Sierra Nevada white fir stands, the threat of defect is not serious in large trees that will be logged within 35-40 years after an insect outbreak.

Forked tops resulting from Douglas fir tussock moth defoliation contained buried leaders

Collapse of an Outbreak Population of the Douglas-fir Tussock Moth, by Richard R. Mason and C.G. Thompson (20)

Three factors may have combined to cause the collapse of an outbreak of the Douglas fir tussock moth in northern California white fir stands in 1966. A major cause of the collapse was probably a natural virus disease in the larval population. However, a late spring frost which destroyed much of the preferred food of the larvae may also have contributed. The number of larvae in a given locale may also have influenced the decline, with the collapse being more rapid in areas where insect populations were highest.

Evaluating Damage Caused to a Campground by Douglas-fir Tussock Moth, by Boyd E. Wickman and Donald A. Renton (21)

In 1964-65, the tussock moth caused heavy damage to white fir in a campground on the Modoc National Forest in California. Researchers sought to determine the impact of the outbreak on the recreation resource. As a result, tree mortality and topkill were tallied and evaluated in a small campground in 1970. Cleanup costs involving hazardous trees and dead tree tops amounted to $23.75 per camp unit. When esthetic values were assigned to the trees, the insect damage costs increased to $126.88 per camp unit.

Flight, Attraction, and Mating Behavior of the Douglas-fir Tussock Moth in Oregon, by B.E. Wickman, R.R. Mason, and H.G. Paul (22)

Knowledge of the reproductive biology of the Douglas-fir tussock moth is important for developing a sex pheromone sampling technique and timing egg mass collections. Adult activity rhythms have been studied in the laboratory, but they have never been determined in the field. This study describes intensive observations and measurements made over a 31-hour period in the Blue Mountains of northeastern Oregon in 1972.

Continuous observations and measurements were made of adult flight, mating, and oviposition. Male flight started at 1000 (P.S.T.), gradually increased to a peak period ca. 1700, and concluded at 1930. This coincided with peak mating activity with the wingless females. Oviposition occurred immediately after mating. Virgin females attached to sticky traps were very effective for attracting and capturing male moths. The female sex pheromone offers a possible technique for early detection of Douglas-fir tussock moth populations.

Armed with vegetation manuals and work books, the group scrambled to check the vegetation on their hillside plots. They decided that a light burn would accomplish the District's objectives. It would consume the dead vegetation and part of the duff. The young pines would be killed. The snowbrush and bitterbrush would sprout in response to heat. The thick bark of the large pines would not be damaged by a low intensity fire, but flame height had to be kept low to prevent crown scorching.

The teams worked out and wrote up their burn plans, mapping the directional exposure of the units, the slope position, and the degree of slope and type of terrain.

The meteorologist from the National Weather Service, in his mobile field unit, supplied essential information to the teams of trainees. He reported wind direction and speed, upper air movement, air temperature, relative humidity, and gave an on-the-spot weather prediction. The air was somewhat moist, the temperature cool, the winds moderate. Conditions were satisfactory.

Each team chose a burning pattern suitable for the plot. Most teams used a combination of patterns: strip head fire, which travels in front of the wind for short distances; backfire, which creeps backward into the wind; or flank fire, which burns across the wind. The torches were lit and burning began.

As smoke from the fires began to block out the blue sky, someone noticed a nuthatch building a nest near the top of a snag. The snag was ringed with retardant and would not burn, but the nuthatch didn't know that. Would she complete her nest or move away? The wildlife consultant wasn't sure. Some questions have not been answered yet, especially in the west where little prescribed burning has been done under tree canopies.

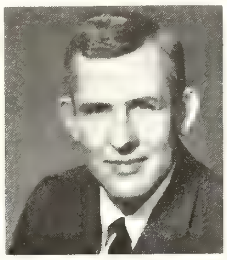
To find some of the answers from the Walker Mountain burn, Len Volland had installed permanent transects the week before. He plans to monitor vegetation response for several years, not only to follow results from the Walker Mountain burn, but to add to general knowledge about prescribed burning in the west.

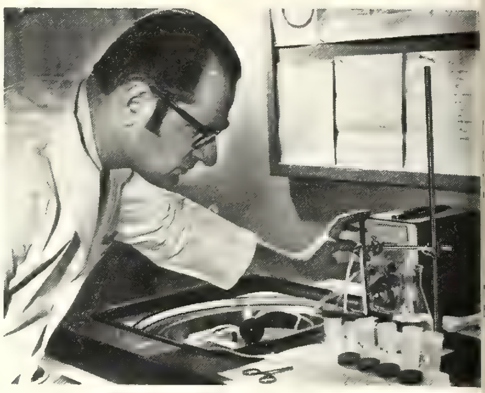
The main purpose of the Walker Mountain burn was to approximate the effects of a low intensity natural fire by removing debris from the forest floor and turning it into nutrients available for new growth. This was the process by which many pine forests had been created and maintained since long before man began managing them.

Population Change in an Outbreak of the Douglas-fir Tussock Moth in Central Arizona, by Richard R. Mason (23)

A study of population density of early stage tussock moth larvae indicates that an outbreak in Arizona developed mainly from populations that had been there for at least 2 years and was not due to the spread of early instar larvae during the outbreak. What this means is that the area of infestation was populated with tussock moths well before the outbreak was apparent. Early instar larvae were not spread long distances by the wind.

Similar to patterns recognized in other outbreaks, the infestation seemed to progress through three phases: release in 1967, a peak in 1968, and decline in 1969. Defoliation was conspicuous in the summers of 1968 and 1969 but disappeared by 1970. Collapse was attributed largely to natural enemies, including a nucleopolyhedrosis virus often associated with tussock moth populations.


Dick Mason


Mauro Martignoni

Development of Sampling Methods for the Douglas-fir Tussock Moth, by Richard R. Mason (24)

Methods were developed to standardize sampling of the Douglas-fir tussock moth. Population density is estimated in terms of the number of eggs or larvae per 1,000 square inches of branch area. Mason indicates that larval sampling is easier than egg sampling because egg masses are clumped in masses and larvae are dispersed over the foliage. This means that fewer samples are required for larval sampling.

See also, *Sequential Sampling of Douglas-fir Tussock Moth Populations,* by Richard R. Mason (25).

Food Preference in a Natural Population of the Douglas-fir Tussock Moth, by Richard R. Mason and Jerrold W. Baxter (26)

The food preferences of the tussock moth were studied in an outbreak on white fir in northern California. Entomologists found that:

- Caterpillars preferred new foliage to old foliage. Old needles were almost totally unacceptable to early instar larvae, but were eaten by older larvae.
- After a late spring frost killed most of the new growth on white fir, many caterpillars shifted to the new needles of ponderosa pine.
- In the laboratory, larvae favored the new growth of white fir over pine needles.
- When caterpillars were fed only frost-damaged foliage (no new growth), many died, apparently from starvation.

Life Tables for a Declining Population of the Douglas-fir Tussock Moth in Northeastern Oregon, by Richard R. Mason (27)

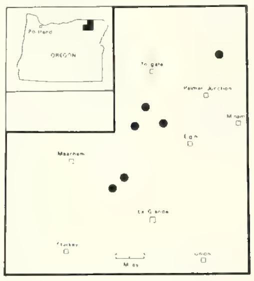
Life tables, a useful technique in the study of population dynamics, provide a format for recording and accounting for all population changes in the life cycle of a species in its natural environment.

The objective of this study was to determine the value of defoliation intensity in the first year that a tussock moth is detected as a predictor of population trend the next year. The evaluation was made by preparing life tables for the generation following detection which show changes in tussock moth population density and the major causes of mortality over a range of stand defoliation conditions.

Rate of decline was variable under different conditions but appeared to be predictable from the level of past defoliation. In general, the decline rate was faster on heavily or moderately defoliated plots than on lightly or previously undefoliated plots.

Population collapse was the result of a multitude of natural factors operating in compensating ways against the high density outbreak. It was characterized by an increase in the effect of numerous mortality factors including virus disease, insect parasites, predators, starvation, and larval dispersion, as well as changes in population quality and structure resulting in lower fecundity, egg quality, and a change in sex ratio.

The largest proportion of mortality occurred early in the larval cycle and was probably due to losses from natural dispersion and predation; however, other factors may have had an equal or greater effect on ultimate collapse of the population although they accounted for less total mortality.



Map shows locations of replicated study areas (•) in northeastern Oregon.

Douglas-fir Tussock Moth: Sex Pheromone Identification and Synthesis, by Ronald G. Smith, Gary E. Daterman, and G. Doyle Daves, Jr. (28)

The sex attractant of the Douglas-fir tussock moth has been isolated and identified chemically as (Z)-6-heneicosen-11-one. The compound has been duplicated artifically in the laboratory and proven highly potent in laboratory and field tests.

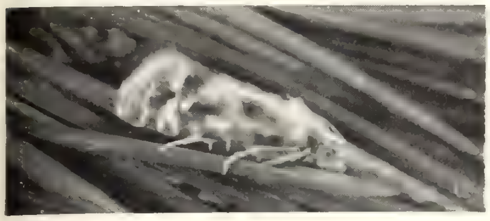
For another technical report on the tussock moth sex attractant, see also the publication listed under (29) in the bibliography.

Considerable research has also been done at the Forestry Sciences Laboratory in Corvallis to develop techniques for using a natural virus of the tussock moth as a control method. Some very technical reports on that work are also listed in the bibliography (30).

Influence of Host Foliage on the Douglas-fir Tussock Moth, by R.C. Beckwith (31)

Douglas-fir tussock moth larvae were fed foliage obtained from the top and bottom of the crowns of Douglas-fir, grand fir, and subalpine fir under controlled laboratory conditions. High density field populations were simulated by forcing larvae to feed upon old-growth foliage creating a stress factor that was detrimental to the population. The host plant and crown position had a significant effect on frass production, head-capsule size, and pupal weight. The number of eggs produced was significantly greater from foliage obtained from the top of the crown. The most significant factor was whether larvae were forced to feed upon old-growth foliage. This "stress" resulted in increased development time, frass production, number of instars in decreased head-capsule size, and egg production.

european pine shoot moth

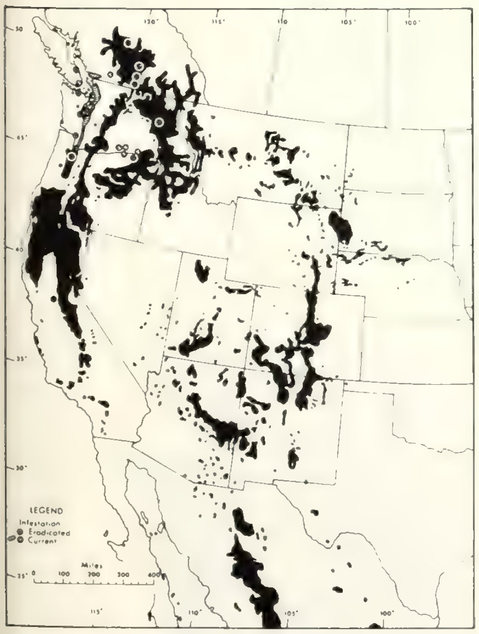


Hazard of European Pine Shoot Moth to Western Pine Forests, by V.M. Carolin, Jr., and G.E. Daterman (32)

Much of the western pine region will be safe from European pine shoot moth damage, principally because of low winter temperatures accompanied by light snow cover. A potential for damage exists in certain areas, however, and the hazard could be particularly high in southern and southwestern Oregon and in northern and central California, where climatic conditions favor shoot moth survival. In some northerly parts of the pine region, local climatic conditions may permit the shoot moth to become an occasional pest.

There are extensive pine stands in the southern Rocky Mountains and in the southern part of the Sierra Nevada in California. There are no records of shoot moth infestations south of 40° N. latitude, but conditions could be suitable for insect survival at higher elevations in that area.

Plantations are especially vulnerable to the shoot moth. Land managers should be particularly alert to shoot moth infestations in young, even-aged stands of ponderosa or lodgepole pine, especially where weather conditions are favorable.



Distribution of European pine shoot moth on ornamental pines in relation to the range of ponderosa pine.

Eradicating Pine Shoot Moth

A series of three reports was prepared in the early 1960's discussing ways to control the shoot moth in forest nurseries and on ornamental pines in residential areas. The following reports are still available:

Eradicating European Pine Shoot Moth on Ornamental Pines With Methyl Bromide, by V.M. Carolin, W.H. Klein, and R.M. Thompson (33)

The introduction of the European pine shoot moth into this region, discovered in 1959, was a potential threat to natural pine stands. To combat this threat, quarantines were invoked and eradication programs undertaken. Destruction of infested areas was initially used as an eradication technique. In the meantime, fumigation with methyl bromide was tested to ascertain its usefulness in eradicating the insect on ornamental pines. Results of this study show that 100-percent control of the shoot moth can be obtained over a wide range of seasonal conditions.

Procedures and Equipment for Fumigating European Pine Shoot Moth on Ornamental Pines, by W.H. Klein and R.M. Thompson (34)

The second in this series reports on procedures and equipment devised for control of European pine shoot moth on single pines and on rows of pines in residential areas and nurseries. Portable chambers of different sizes and shapes were developed, precise application devices were fabricated, and devices for safe evacuation of the gas from the chambers were devised. Methods of controlling the gas concentration and proper use of equipment are also described.

Eradicating European Pine Shoot Moth in Commercial Nurseries With Methyl Bromide, by V.M. Carolin and W.K. Coulter (35)

The third publication in this series reports on the feasibility of eradicating European pine shoot moth in a commercial nursery. Fumigation methods devised earlier were modified for the treatment of groups of trees and rows of trees.

Results indicate that fumigation of an entire commercial nursery is feasible under conditions existing in the Puget Sound area of Washington during late fall and winter. Temperature ranges in chambers of 40° to 65° are acceptable. When tarps were used under the fumigation chambers, treatment resulted in 100 percent control of the shoot moth. Wet soil alone was less successful. Tree damage from fumigation was minor and most apparent on lodgepole pine and western white pine.

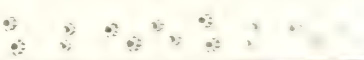
Even man's management has included planned burning. The Indians did it. So did the early stockmen. Farmers still burn. But, since the early 1900's, the efforts of most public agencies have been to prevent and suppress the large destructive wildfires that damage thousands of acres of forest and range. The benefits of fire were ignored. As dead vegetation piled up in the forests, becoming fuel for the devastating fires the agencies were trying to prevent, land managers became concerned and began to consider the possible benefits of controlled fire.

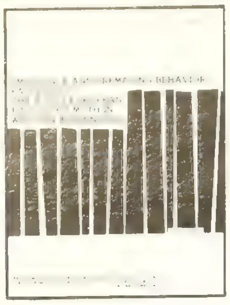
Prescribed burning was first used in the South in the 1930's, and its acceptance has gradually spread to other parts of the country. In addition to reducing the hazard of dead vegetation, burning is now also used to accomplish silvicultural objectives—preparing sites for seeding and planting, controlling insects and disease, and manipulating species—and to improve cattle forage, wildlife habitat and browse, and accessibility within stands.

Many foresters who have had experience with prescribed burning feel it is environmentally sound and is bound to become more important in the future. It is a dramatic and powerful tool—potentially effective if used with respect by trained people, but dangerous if abused.

Acceptance by foresters of prescribed burning in the west made the workshop both possible and necessary. There were more applicants than could be accepted, and annual sessions for the next several years are planned. Like the one held in 1976, future workshops will include field work. John Dell, one of the workshop organizers, feels this was an important feature. "The students had an opportunity to work on an operational burn—to get a feel for the whole process from the first steps in planning to completion. They now have a foundation on which to build," he said. Two of the instructors, fire scientists Jack Dieterich and Steve Sackett of the Rocky Mountain Station, felt that the Region-wide basis of the workshop reflected recognition of the importance of fuel management problems.

One of the students, Paul Haertel, of the Lava Beds National Monument in northern California, said he was reassured by the interest of other agencies in burning. For the past three years the Monument staff has been involved in a fire ecology research project with the University of Washington.





Emergence and Premating Behavior Patterns of the Adult European Pine Shoot Moth in Western Washington, by W.K. Coulter (36)

The European pine shoot moth was discovered in 1959 infesting ornamental pine in Bellevue, Washington. Quarantines were invoked, techniques developed for pest control by tree fumigation, and in 1964 a research program was begun to investigate procedures for eradication by the sterile-male release technique.

One phase of the research program was to record the biological characteristics of the adult shoot moth which were pertinent to the release and dispersion of sterilized males. This paper discusses emergence and premating behavior and deals mainly with observations of adult activity on the twig or tree from which the adult emerged.

Patterns of diurnal activity provide a guide for liberating sterile males at a time of day so that they can compete with wild males for the attention of wild females.

Survival of European Pine Shoot Moth Under Caged Conditions in a Ponderosa Pine Forest, by G.E. Daterman and V.M. Carolin, Jr. (37)

For this study, forest entomologists lived dangerously and took specimens of the European pine shoot moth, an introduced pest, and put them on forest trees that had been caged to keep the insects in. Purpose of the experiment was to evaluate the potential threat of the shoot moth to native forests.

Results indicate the geographic areas where shoot moth might become established. Most likely locations are southern Oregon and California north of 40° N. latitude. The least likely locations are in interior British Columbia, Alberta, some locations in northern Washington and northeastern Oregon, Idaho, Montana, Wyoming, Nebraska, and the Dakotas.

A limiting factor appears to be low winter temperatures that kill overwintering larvae.

For other information about the environmental factors that might influence survival of shoot moth in the forests, see also a very technical paper by Daterman on the effects of temperature and vapor pressure on egg production and survival (38).

Parasites of Shoot Moth Released

Itoplectis quadricingulatus is the Latin name for a parasite of the European pine shoot moth, otherwise known as *Rhyacionia buoliana*! These parasites are native to this country and were found to attack the shoot moth when it moved into the West. So research entomologists decided to try releasing them in an ornamental pine planting in western Washington to see if they had any potential in an integrated control program.

A total of 5,365 female parasites were released on a 40-acre site over a 7-week period when pupae of the pine shoot moth were known to be present. Parasitization of the shoot moth increased by 30 percent.

For details, see the technical report, *Test Release of* Itoplectis quadricingulatus *Against European Pine Shoot Moth in an Isolated Infestation,* by Roger B. Ryan and Richard D. Medley (39).

Sex Pheromone of the European Pine Shoot Moth: Chemical Identification and Field Tests, by Ronald G. Smith and others (40)

The sex attractant of the European pine shoot moth has been isolated and identified chemically as (E)-9-dodecenyl acetate. As a result, the synthetic version of the attractant has been prepared in the laboratory and later tested in the field. Results were good, with the synthetic material consistently attracting more moths than traps with female moths! The effectiveness of this material indicates a high potential for detection and perhaps suppression of shoot moth infestations.

Synthetic Sex Pheromone for Detection Survey of European Pine Shoot Moth, by Gary E. Daterman (41)

The sex attractant or pheromone of the European pine shoot moth is a chemical compound emitted by receptive females to "call" males for purposes of reproduction. This "come-hither" scent is now available in synthetic form and can be utilized in a very sensitive trapping device to indicate the presence or absence of the insect in a particular area.

Methods are outlined for using the attractant in a detection survey program. The report discusses suitable trapping devices, pheromone doses, trap placement, and the importance of trapping when male moths are in flight.

For other highly technical reports on the sex attractant of the pine shoot moth, see also items listed under (42) in the bibliography.

Adhesive trap showing captured R. buoliana *males and pheromone-plastic bait suspended on pin (arrow).*

lodgepole needle miner

Forest-Site Relationships Within an Outbreak of Lodgepole Needle Miner in Central Oregon, by Richard R. Mason and Timothy C. Tigner (43)

Entomologists studied the relationship between forest site and stand conditions to outbreaks of the lodgepole needle miner in central Oregon.

Results clearly show that site influenced the distribution of needle miner outbreaks. High insect populations occurred only in pure stands in broad basins where lodgepole is considered the climax species. The probable risk of sites to needle miner infestation are as follows:

Pinus contorta/Purshia tridentata community—High risk.

Pinus contorta/Arctostaphylos uva-ursi community—Low risk.

Pinus contorta/Purshia tridentata-Arctostaphylos patula community—or—*Pinus ponderosa/Purshia tridentata-Arctostaphylos patula* association—Low risk.

Resistance to a Needle Miner in Lodgepole Pine Varies With Foliage Source, by T.C. Tigner and R.R. Mason (44)

The ability of lodgepole pine to resist defoliation by the needle miner is related to forest-site characteristics, tree age, and location of foliage in the crown of the tree. In fact, the major cause of differences in defoliation is probably the varying quality of the foliage. There is evidence to indicate that some tree foliage contains a compound that makes it resistant to munching by the needle miner.

Gary Daterman

larch casebearer

Photoperiod Effects on Development of the Larch Casebearer, by R.B. Ryan (45)

The larch casebearer is an introduced pest that is currently causing serious defoliation to some stands of larch in the West. Insect parasites are being introduced in an effort to bring this pest under biological control.

In order to raise parasites for the control program, it is also necessary to raise its host—the larch casebearer. In spite of several comprehensive studies on the biology of the larch casebearer, no one has previously studied the effects of photoperiod or published methods for rearing these insects through several generations in the laboratory.

In this paper, Ryan discusses the effects of photoperiod on insect development. Pupation is controlled by specific long-day and short-day sequences.

Attainment of the Overwintering Instar and the Casebearing Habit by Larch Casebearer Larvae at Different Elevations in the Blue Mountains, by Roger B. Ryan (46)

In order to know exactly when to release parasites to control the larch casebearer, entomologists must know more about the development of the insect through its several larval instars.

Ideally, parasites attacking the casebearer stage should be released in the fall when the larvae has reached the third, or over-wintering instar, but not before. At this time, the larvae wears a protective shell from which it gets its name, the larch casebearer.

Ryan found that larvae at 4,000-feet elevation advanced more rapidly than larvae at either higher or lower elevations. Based on this data, parasite releases should be delayed until mid-September, after which parasites would find some suitable hosts at all elevations.

See also a technical note describing the length of time it takes for casebearer larvae to become active again after over-wintering (47).

Roger Ryan

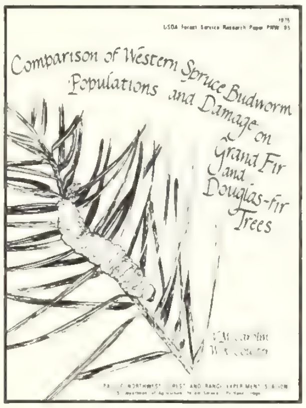
Parasites of the Larch Casebearer

A total of 240 *Chrysocharis laricinellae* and 513 *Dicladocerus westwoodii* (Hymenoptera: Eulophidae) from Austria and England were released in Washington and Idaho in 1972. This is the first attempted establishment of these parasites in western North America for biological control of the larch casebearer.

This information is found in *Initial Releases of* Chrysocharis laricinellae *and* Dicladocerus westwoodii *for Biological Control of the Larch Casebearer in the Western United States,* by R.B. Ryan and R.E. Denton (48).

For other technical reports on parasites of the casebearer, see publications listed under (49) in the bibliography.

western spruce budworm



USDA Forest Service Research Paper

Comparison of Western Spruce Budworm Populations and Damage on Grand Fir and Douglas-fir Trees

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

Comparison of Western Spruce Budworm Populations and Damage on Grand Fir and Douglas-fir Trees, by V.M. Carolin and W.K. Coulter (50)

The increasing abundance of grand fir in mixed conifer forests of eastern Oregon and Washington may increase the danger of damage from the spruce budworm. This study shows that grand fir is more heavily damaged by the budworm than Douglas-fir. The percent of new growth in grand fir that is defoliated is an indicator of the degree of damage, but bud-killing and top-killing are more meaningful when damage is heavy.

Attractants for Spruce Budworm

Research indicates that a sex attractant of the male spruce budworm of the species *Choristoneura fumiferana* and *C. occidentalis*, is also attractive to the male green budworm, *C. biennis.* A slightly modified chemical attractant is also attractive to the male green budworm, *C. viridis.*

See the paper *Sex Attractants for Two Species of Western Spruce Budworm,* Choristoneura biennis *and* C. viridis *(Lepidoptera: Tortricidae),* by C.J. Sanders, G.E. Daterman, and others (51).

They hope to work into a burning program to duplicate the natural cycle of fires in the area, burning every 7 to 10 years.

Bob Martin, who helped organize this workshop and has also been involved with the experimental burning at Lava Beds Monument, said he especially wanted the students to have field experience in addition to classroom work: "They found out it's not the same as slash burning. You can't hurry burning under a stand and stick to your objectives for flame and scorch height."

And what happened at Walker Mountain? Good fuel reduction was achieved. The younger pines were killed. However, some of the larger lodgepole were also killed in an area that got a little hotter than planned. Conditions for wildlife were improved. Three months after the burn, Volland found deer at Walker Mountain, attracted by their favorite browse—sprouts from the root crowns of ceanothus. "It's like ice cream to them," he said.

end

TRUFFLES BELIEVED VITAL TO FOREST ECOSYSTEM

by Bob Mowrey

Our ideas about truffles, rodents, and trees usually carry old and familiar connotations. Truffles: savory condiment for the wealthy gourmet. Rodents: pests and consumers of the conifer seeds intended for reforestation. Trees: timber, efficiently competitive and towering over all the plants of the forest. However, there is actually a very delicate and balanced interrelationship between many species of fungi, mammals, and plants that is important for the forester to keep in mind.

New insight on how Northwest forest ecosystems function is being gained through integration of information from studies of fungal taxonomy, food habits of small mammals, the nutrient uptake of trees, and the inoculation of conifer seedlings with fungi in nursery experiments. At the Corvallis Forestry Sciences Laboratory of the PNW Station, Dr. James Trappe of the Forest Service and colleague Dr. Edward Trione of the Agricultural Research Service are conducting research on species of fungi which interact with rootlets of plants in a mutually beneficial fashion, called a symbiotic relationship.

Sampling Populations of Western Spruce Budworm and Predicting Defoliation on Douglas-fir in Eastern Oregon, by V.M. Carolin and W.K. Coulter (52)

The western spruce budworm is a serious forest pest in Western United States. Predictions of damage a year in advance are needed, to make realistic plans for direct control. In the Pacific Northwest, the principal hosts—those on which greatest economic damage occurs—are Douglas-fir and grand fir. Emphasis was placed on predictions for Douglas-fir.

Studies were initiated in 1950 to develop methods for sampling the life stages of the insect and estimating defoliation that will occur. Costs were considered, as well as variance of sample estimates, so that efficiency could be used as a basis for recommending surveys at specific life stages. The study area was in the Blue Mountains of eastern Oregon which contained epidemic infestations of the budworm from 1946 to 1959.

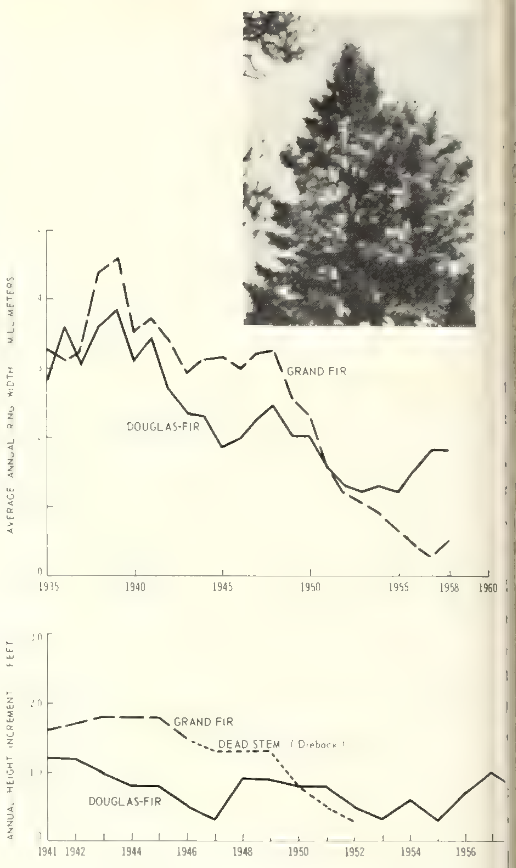
Researchers found that it is possible to predict defoliation with some accuracy. Tables were developed to show egg mass density, corresponding density of larvae in the buds, and the degree of defoliation that will occur. Requirements for surveys during both the egg stage and the bud-mining period are presented, with options as to sampling error survey people are willing to accept.

Differential Effects of the 1944-56 Spruce Budworm Outbreak in Eastern Oregon, by Carroll B. Williams, Jr. (54)

There are differences in the way various trees respond to damage by defoliating insects. The most noticeable differences are usually associated with tree species. For example, the spruce budworm causes most damage to true firs, Douglas-fir, and Engelmann spruce.

The general trend of large larval populations is forest damage by: severe defoliation, reduction of the normal vegetative bud complement, top-killing, reduction of annual growth, and finally, tree mortality.

This study was conducted to determine the differences among grand fir, Douglas-fir, and Engelmann spruce in susceptibility to damage. The study was conducted in 1958-59 in four forest stands in the Wallowa-Whitman National Forest in Oregon. Four case histories are given. The general conclusion is that damage is most severe and most variable on grand fir, intermediate on Engelmann spruce, and least on Douglas-fir and ponderosa pine. Budworm populations may tend to be greater on grand fir than on other species and/or similar populations may do more damage to grand fir.



Annual increment comparisons and a photograph of a heavily damaged grand fir and an adjacent, lightly damaged Douglas-fir which appeared to be competing with each other. The grand fir had the higher growth rate and was rapidly overtaking the Douglas-fir until feedings by spruce budworm killed its top and reduced its growth rate more than that of the Douglas-fir.

Effects of DDT Spraying

What are the effects of DDT on populations of the western spruce budworm? Entomologists studied long-term population trends from 1951 to 1959 at several locations sprayed either in 1949 or 1950 in the course of a large-scale control project. Also, in 1957-60 at other locations they compared densities of associated defoliators and spruce budworm before and after spraying. A special part of their study was to evaluate the effects on parasites of the budworm.

Results indicate that the DDT spraying resulted in effective suppression of the spruce budworm, with only minor and temporary effects on its complex of parasites. Less than 1 percent of the treated area was resprayed and development of DDT resistance seems unlikely. The DDT spray program neither shortened nor extended the duration of the outbreak, but it saved much valuable timber for future use by reducing population levels.

Details are found in *Trends of Western Spruce Budworm and Associated Insects in Pacific Northwest Forests Sprayed with DDT,* by V.M. Carolin and W.K. Coulter (53).

western hemlock looper

Sampling Egg Populations of Western Hemlock Looper in Coastal Forests, by V.M. Carolin, N.E. Johnson, P.E. Buffam, and D. McComb (55)

The western hemlock looper periodically causes severe damage in coastal forests of Oregon, Washington, and British Columbia. Improved survey methods are needed to detect infestations before damage occurs and to express hazard by estimates of egg populations. Cooperative sampling studies by the Forest Service and Weyerhaeuser Co. were conducted in the winter of 1962-63 to improve existing survey techniques.

Results show that the best sampling units for detecting looper infestations are mossy log surfaces and bole sections. Most eggs are laid on moss on roughened bark and flat lichens on smooth bark. The best method for estimating egg populations is to fell the tree and sample the bole at midcrown; this verifies a finding based on studies in British Columbia.

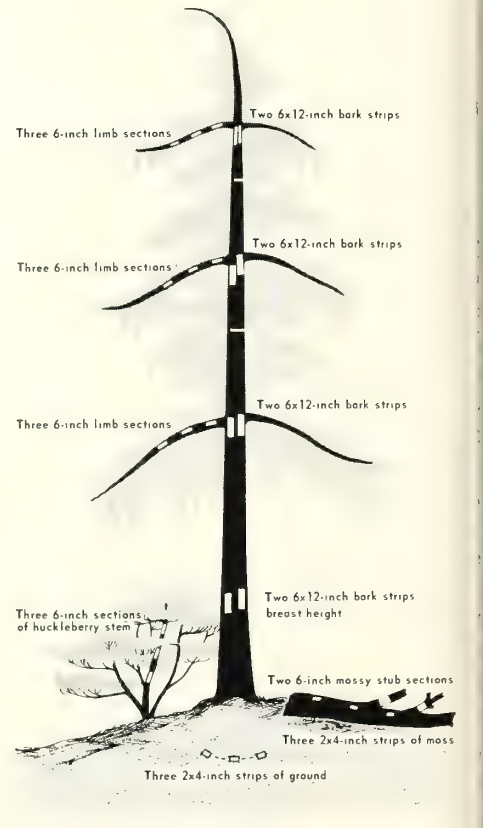
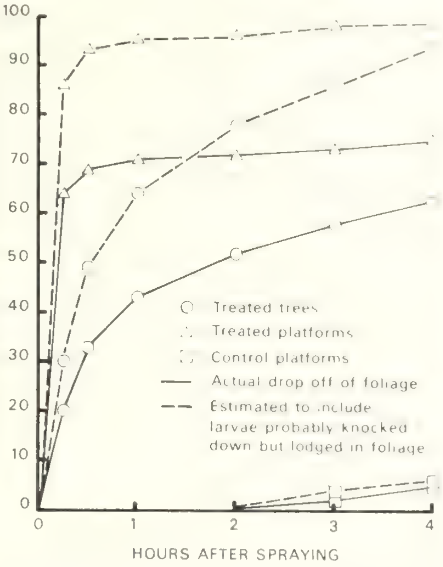

Two 6x12-inch bark strips
Three 6-inch limb sections
Two 6x12-inch bark strips
Three 6-inch limb sections
Two 6x12-inch bark strips
Three 6-inch limb sections
Two 6x12-inch bark strips breast height
Three 6-inch sections of huckleberry stem
Two 6-inch mossy stub sections
Three 2x4-inch strips of moss
Three 2x4-inch strips of ground

Diagram of sample tree and its understory area, showing location of subsamples.

Controlled Field Test of Stabilized Pyrethrins Against the Western Hemlock Looper, by Richard R. Mason (56)

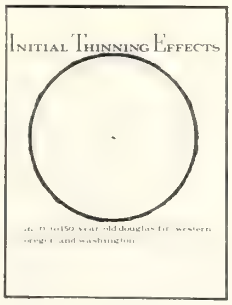
Pyrethrins are natural insecticidal compounds usually extracted from flowers of the pyrethrum plant. They are highly toxic to many lepidopterous defoliators including the western hemlock looper. Moreover, they have a low level of toxicity to mammals and are generally regarded as among the safest of insecticides. However, because of their rapid deterioration in sunlight, previous ormulations of pyrethrins have been of little value in controlling forest defoliators.

Recently, a stabilized formulation of pyrethrins has been developed that shows promise of maintaining toxicity in direct sunlight for a relatively long time. It was field tested against larvae of the western hemlock looper by spraying from a helicopter. Larvae were placed in foliage on platforms where they were fully exposed to the spray and on small trees where they were partially screened from direct spray contact. Ninety-nine percent and 94 percent of the larvae on the platforms and on the trees, respectively, were paralyzed or killed by the insecticide. Most of the larvae fully exposed on the platforms were knocked down within a few minutes after spraying, whereas knockdown of larvae in the trees occurred over a considerably longer period of time.



Drop off from foliage and estimated knockdown of hemlock looper larvae in relation to time after spraying.

effects of forest management


INITIAL THINNING EFFECTS

in 70 to150 year old douglas fir western oregon and washington

Initial Thinning Effects in 70- to 150-Year-Old Douglas-fir—Western Oregon and Washington, by Richard L. Williamson and Frank E. Price (57)

The Douglas-fir beetle rarely attacks trees less than 60 years old. In older trees, mortality may be reduced 60 percent by thinning. This conclusion comes from study of nine areas in western Washington and Oregon. These study areas have been observed for an average of 13 years each. In addition to redistributing growth to fewer, higher quality trees and providing an earlier income, thinning appears to have improved health and vigor of residual trees. This effect is believed to be primarily responsible for the observed reduction of bark-beetle mortality.

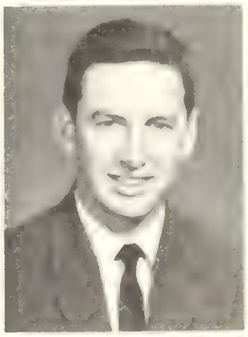
The experience of these plots through the 1952, 1959, and 1968 bark beetle epidemics indicates a major advantage of thinning over sanitation-salvage cutting. Thinning can evidently curtail such epidemics in mature young growth and, perhaps more important, drastically reduce normal, endemic, bark-beetle mortality.

Effects of Fertilization

Douglas-fir usually responds to nitrogen fertilization with increased growth and a detectable improvement in foliage color. Forest insect populations can also be affected. For example, nitrogen has been shown to reduce the number of some species of defoliators, bark beetles, and weevils but sometimes stimulates populations of sucking insects.

In Douglas-fir, the Cooley spruce gall aphid is a common and important sucking insect pest of Christmas tree plantations. In this study, entomologists set out to learn what effect fertilization would have on this pest. What they found was mixed—fertilization increased egg laying and winter survival, but aphid establishment was reduced. Two years after fertilization, the population levels were essentially the same on fertilized and unfertilized trees.

See *Field Fertilization of Douglas-fir and Its Effect on* Adelges cooleyi *Populations,* by R.G. Mitchell and H.G. Paul (58).



Russ Mitchell

Nine additional researchers at Corvallis, four scientists and five graduate students, are collaborating with Trappe and Trione in specialized areas of concern with regard to mycorrhizal fungi. Microbiologist Dr. K.C. Lu is studying the kinds of bacteria that surround mycorrhizae in the soil. Plant pathologist Iwan Ho is investigating the enzymes of mycorrhizal fungi and other physiological traits. Botanist Randy Molina is working on the selection and nursery inoculation of mycorrhizal fungi. Microtechnician Darr Duff assists in aspects of analysis and in preparation of fungi for microscopic examination. The graduate students have each designed their own research projects and are further studying the complex characteristics of mycorrhizal fungi.

When the mycelium of a beneficial fungus and the rootlet of a plant combine, they form what the scientists term a mycorrhizal association. Almost all plants, whether grass, forb, shrub, or tree, depend on such an interaction with fungi to survive and develop normally under natural conditions. In fact, in reforestation work most Douglas-fir seedlings die soon after planting if there are no mycorrhizal fungi present in the soil.

At the Corvallis laboratory research is presently underway in cooperation with the Weyerhaeuser Company on inoculation of conifer nursery seedlings with selected mycorrhizal fungi. The goal is to discover which fungi can potentially and dramatically improve the survival and growth of seedlings after outplanting. At the laboratory several thousand seedlings were grown from the seeds of Douglas-fir, ponderosa pine, and western hemlock. The seedlings were grown for about 6 months in containers of vermiculite and peat moss inoculated with mycorrhizal fungi common to the three conifer species. Pure laboratory cultures of four species of fungi were used in the inoculations. Each is widely distributed in western forests.

In the spring of 1976 these seedlings were planted on Weyerhaeuser tree farms near Mount St. Helens, Washington, and Klamath Falls, Oregon. When measurements of seedling survival and growth are completed in 1978, the researchers will be able to better advise foresters which of the four species of fungi show most promise for aiding seedling establishment on comparable sites in the Pacific Northwest. The program on mycorrhizae research is continuing as the researchers seek to discover the most suitable fungi to use in improving reforestation success.

Insects in the Young Stand of Douglas-fir and Hemlock, by R.G. Mitchell (59)

Entomologist Mitchell discusses the situation with regard to insects in young-growth stands—"We're not exactly sure where we're going, but we're getting there awfully fast. We have little experience in dealing with problems in young stands; indications are that the problems of the future will be quite different from those experienced in the past. And intensively managed stands will be particularly vexatious." A quick summary:

Disappearing Problems: Douglas-fir and other bark beetles; ambrosia beetles, flatheads, roundheads, horntails, and other insects that cause degrade in lumber.

Continuing Problems: Insects that feed on needles including spruce budworm, hemlock looper, black-headed budworm.

New Problems: Ants, woolly aphids, needle-mining midges, weevils; cone and seed insects; grubs; mites, cutworms; defoliators; and twig miners.

Disease and Insect Activity in Relation to Intensive Culture of Forests, by Keith R. Shea (60)

Intensive cultural practices influence susceptibility to destructive forest insects and diseases. New forests are being created throughout the world, often with a single native species or an exotic one. Old and new management techniques are being applied with increasing intensity: artificial regeneration of contiguous areas with trees selected for rapid growth or other genetic advantages, fertilization, frequent intermediate cuttings, continuous cropping, and a high degree of mechanization. The effects of these practices upon insect and disease incidence are often unknown or, at best, poorly understood.

In the new, intensively managed forests, insects and diseases will have greater significance. Potentially damaging insects include those affecting twigs, terminal shoots and buds, sucking insects, defoliators, and those feeding in the inner bark and cambial regions. Root rots (including diseases of fine roots), foliage diseases, and stem cankers also are likely to increase in importance as will physiogenic disorders and diseases due to obscure or complex causes. In some cases, seemingly innocuous diseases and insect vectors jointly will create particularly vexing problems.

Broadly based research programs need to accompany development of intensive cultural practices.

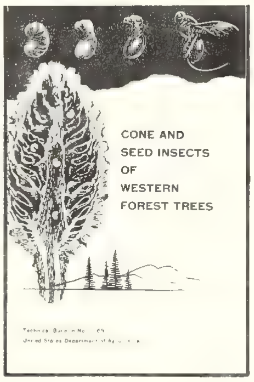
A multidisciplinary research approach is indicated.

The Silvicultural Importance of the Sitka Spruce Weevil in Coastal Oregon and Washington, by K.H. Wright and D.H. Baisinger (61)

The Sitka spruce weevil is a pest of young Sitka spruce in coastal Oregon, Washington, and British Columbia. The weevil attacks the terminals of trees, reducing height growth and deforming the tree. By 1951, the damage had become so severe that a study was undertaken in Clatsop County, Oregon, to evaluate the problem and develop control measures.

Results of the study indicate that hemlock will eventually dominate Sitka spruce in the area studied. The weevil is a major causative factor.

No chemical control measures have been developed for the Sitka spruce weevil. Before such measures can be developed, more information regarding the biology and habits of the insect is needed.



CONE AND
SEED INSECTS
OF
WESTERN
FOREST TREES

Cone and Seed Insects of Western Forest Trees, by F.P. Keen (62)

Published in 1957, this 168-page book is still an authoritative source of information on cone and seed insects even though more recent work has been published.

Insects that destroy the seeds of forest trees have an important bearing on reforestation. If a high percentage of a seed crop is destroyed in any year, seed collecting may be unprofitable, and nursery establishment and planting will be greatly hampered. Also the loss of seed may seriously threaten the natural reestablishment of commercially valuable tree species on burned or cutover lands, where timing of seeding may be highly critical.

The book has two main topics: (1) a discussion of the western forest trees and a listing of the cone and seed insects which attack each, and (2) a review of the biology and habits of the cone and seed insects and their insect enemies. Additional information is given on control of the insects and needs for further study.

Susceptibility of 10 Spruce Species and Hybrids to the White Pine Weevil (Sitka Spruce Weevil) in the Pacific Northwest, by R.G. Mitchell, N.E. Johnson, and K.H. Wright (63)

Ten different species and hybrids of spruce were studies on 3 plots for some 16 years to determine their growth rate and susceptibility to the white pine weevil in coastal Oregon and Washington.

The conclusion is that both Norway spruce and Lutz spruce (a natural hybrid of white and Sitka spruce) grow well in the coastal environment. However, because of its low susceptibility to weevil attack, Lutz spruce is a more promising replacement for the heavily weeviled Sitka spruce. Norway spruce was very susceptible to the weevil. Lesser damage was also observed on black spruce, white spruce, and Engelmann spruce.

Damage to Sitka spruce by Pissodes strobi. *A. Weevil larvae mine down the terminal shortly after bud burst and, in midsummer, form pupal cells under the bark at the end of the mines.*

B. New growth arising from attacked terminal dies and starts to droop when the mining larvae grow large enough to sever conductive tissue.

C. Multiple tops often develop when laterals below the killed terminal assume dominance.

D. Killed terminals overgrown by laterals-turned-to-leaders result in poor stem form and decreased wood quality.

control, aerial application techniques

Aerial Photographic Techniques for Estimating Damage by Insects in Western Forests, by J.F. Wear, R.B. Pope, and P.W. Orr (64)

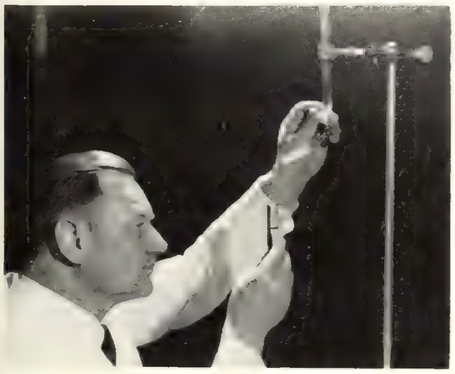
A manager, responsible for administering forest lands, needs to keep a constant check on the status of the forest resource and the changes that have taken place, or are likely to take place. Among the kinds of information he needs is that on the damage caused by forest insects. Such knowledge may affect his decisions on the amount of allowable cut, his plans for the orderly harvest of timber, the salvage of dead or damaged material, and the control of insect outbreaks.

Keeping track of this damage is usually a difficult and expensive task because the mortality is typically scattered in erratic fashion over vast and often inaccessible areas. Often, excessively high costs can be avoided by using aerial photography, which covers ground more quickly and cheaply than fieldwork, yet provides a permanent in-place record of certain kinds of damage. This manual summarizes the present state of knowledge in this field and presents step-by-step procedures for the best known applications of aerial photography to forest insect surveys in the West.

Users should try to get an original copy of this report, as there are several color plates that black and white will not do justice to.

Aerial Applications of Insecticides on Forests in the United States, by Charles Sartwell and David Alligood (65)

Part of a study on pest control for the National Research Council, this report gives information on the forest areas sprayed for various pests from 1945-1974, the acreages sprayed, the chemicals used, and the target species.



Bohdan Maksymiuk

Kinetics and Physics of Pesticidal Aerial Sprays, by Bohdan Maksymiuk (66)

Fundamental knowledge of the kinetics and physics of sprays is essential for improving aerial application of pesticides. Spray kinetics deals with production of spray drops, while spray physics deals with spray behavior, pattern of dispersal, and deposition. Effectiveness and safety of aerial application of pesticides depends on maximum target coverage with minimum dose and spray volume, and reduction of drift hazards.

Factors affecting target coverage and spray deposit assessment are discussed. Improved aerial application technology will result in more efficient distribution of insecticide on the plant, which in turn, will mean a more favorable cost-benefit ratio for the pest control programs.

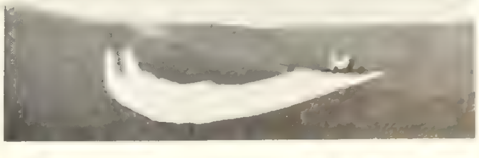
Zectran for Spruce Budworm Control

Mexacarbate, or Zectran^R, has been recommended by the U.S. Forest Service as a replacement for DDT for control of the western spruce budworm, the spruce budworm, and jack pine budworm. (Unfortunately Zectran is no longer available as it is not being produced commercially.) Mexacarbate is considered environmentally safe, but past field trials often produced results too erratic for operational use against the western spruce budworm.

In tests with mexacarbate, the erratic and occasionally low spruce budworm mortalities have been hypothesized to be the result of variable and insufficient target coverage. To test this hypothesis, we conducted a detailed investigation, under typical field conditions during a large-scale pilot-control study, using mexacarbate against the western spruce budworm in northern Idaho.

This paper reports droplet size spectra of deposits at the forest floor level, deposit coverage of the forest canopy, quantity and variation of deposit distribution reaching the forest floor, and correlation of spray deposit on tree foliage with the larval mortality.

See the very technical report *Distribution of Aerially Applied Mexacarbate in a Coniferous Forest and Correlation With Mortality of* Choristoneura occidentalis *(Lepid., Tortricidae)*, by Maksymiuk, Neisess, Waite, and Orchard (67).



C-47 applying mexacarbate in study area showing spray cloud

In the mycorrhizal association, the fungus aids the tree in absorbing nutrients and water, protects it from harmful fungi, and produces growth regulators that foster increased growth while prolonging the life of the rootlets. The fungus forms a protective mantle around the rootlets and in return gains carbohydrates and other photosynthetic products from the tree.

In the Northwest there are more than 2,000 species of fungi which form mycorrhizae with Douglas-fir alone. The fruiting bodies of most of these fungi are the common fleshy mushrooms found on the surface of the ground under host trees. However, several hundred species bear fruiting bodies which develop entirely underground; these are the truffles and false truffles.

While mushrooms normally reproduce by sending out their spores on the wind, truffles depend on small mammals to eat them and transport their spores to new locations. Deer will also eat truffles, but primarily it is the small rodents that consume them in the Northwest. When mature with spores, truffles take on a distinctive odor which enables the animals to locate them.

Truffles come in many colors: delicate shades of white, yellow, brown, blue, green or red. They are from 1 to 4 inches in diameter, or may be even smaller, and look like little wrinkled potatoes.

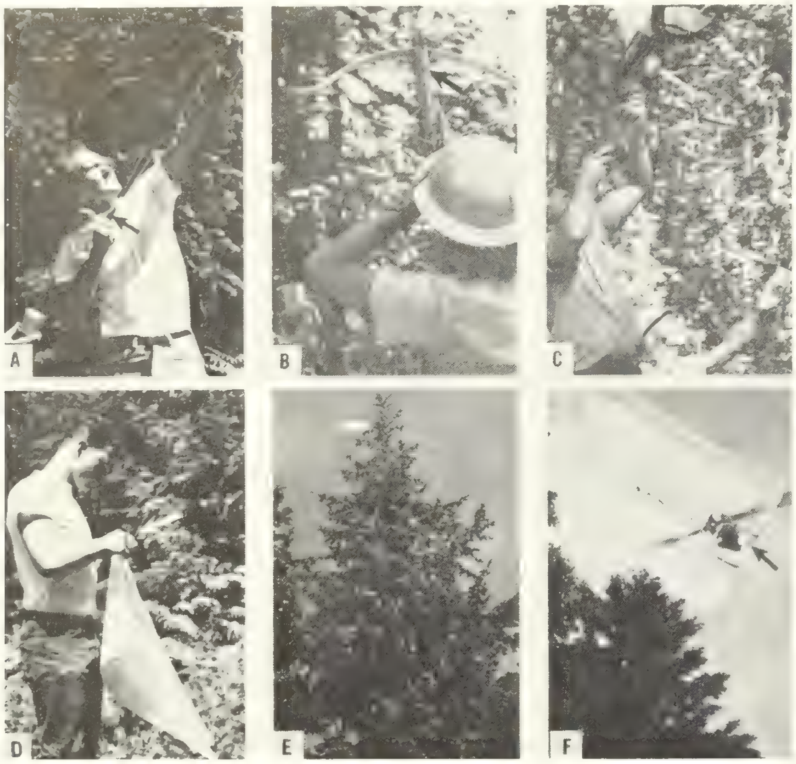
For years, Northwest foresters have looked upon small rodents as highly detrimental because most of them eat the seeds of conifers, which hampers reforestation attempts. However, Trappe's research provides us with a different perspective. Working in collaboration with BLM biologist Chris Maser, Trappe examined the stomach contents of over 500 small rodents of 25 different species and found that fully 80 percent of them took some fungi in their diets. Some of the squirrels, chipmunks, mice, and voles, in fact, feed extensively on truffles. Trappe contends that this interaction between truffle and animal is actually an extremely important ecological relationship.

The ecosystem benefits from the fungus-animal interaction. When eaten, the truffle is digested except for the spores. After passing through the animal's digestive tract, the spores are still viable when deposited in the fecal pellets. As the animals move about

Marking Methods for Improving Aerial Application of Forest Pesticides, by Bohdan Maksymiuk (68)

Markers that are readily visible to the pilot are essential for proper identification of the boundaries of treatment areas and spacing of application swaths. They increase accuracy, efficiency, and safety of aerial application of pesticides and other materials.

Methods for placing marking panels in the treetops are described. The slingshot and crossbow methods are satisfactory for marking trees under 100 feet in height. The line-throwing gun can be used for marking trees up to about 150 feet tall and possibly taller, depending mainly on the load of power charges, ballistics of missile, weight of line, and firing angle. Helium-inflated balloons, protruding above the forest canopy, also are useful navigational aids. Other marking methods are also described and reviewed.



Marking trees from the ground: Projectiles (sinker, bolt, missile) attached to the monofilament line are catapulted over the treetop with the slingshot (A); crossbow (B), and line-throwing gun (C); projectile is removed and the line attached to the marking panel (D); hoisted panel is shown in treetop (E); a pair of captive helium-inflated balloons (F) can be seen above the treetops (in shadow of the helicopter).

How to Minimize Drift of Pesticidal Sprays, by Bohdan Maksymiuk (69)

Drift from herbicides and insecticides poses a potentail hazard to non-target organisms and increases residue problems in plants, animals, air, and water. In general, the potential drift hazard is greater from aerial application of herbicides (such as 2,4-D, 2,4,5-T, and amitrole) than from insecticides because of the chemical nature of herbicides and their patterns of use.

The quantity and extent of drift can be reduced by a combination of several interrelated factors such as spray formulation, equipment, and atomization, meteorological factors, and spraying method. Research for developing effective and safe technology for aerial application of herbicides in forestry is lagging behind that for aerial application of insecticides.

Bell Helicopter Evaluated

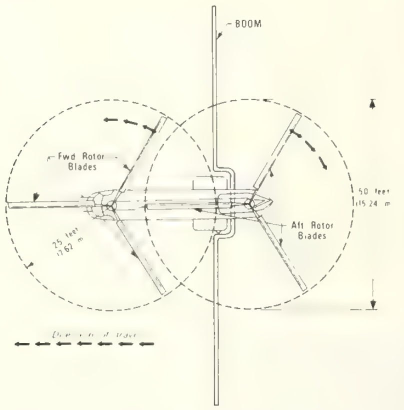
The atomization and distribution of insecticide sprays produced from a Bell 205A-1 turbojet helicopter and spray system were evaluated. The degree of atomization was within the same range as that produced by the smaller helicopters, and the acceptable swath width was wider. In some flights there were two very high deposit peaks similar to that produced by a fixed-wing aircraft spraying at a low height above the ground. By visual observation, the main rotor vortexes appeared stronger and more pronounced than those of smaller helicopters. On a large forest spray program, the Bell 205A-1 sprayed an average of 877 acres per hour at an application rate of 1 gallon per acre for a cost of $1.78 per acre.

This information is found in a research note, *Evaluation of the Bell 205A-1 Turbojet Helicopter and Spray System for Forest Application of Insecticide,* by Richard D. Orchard and others (70).

Boeing Helicopter Evaluated

The distribution of insecticide sprays produced from a Boeing-Vertol 107 helicopter and spray system was evaluated. The Vertol produced a spray pattern similar to that of other helicopters and was found suitable for forest spraying. The swath width varied with the nozzle arrangement on the boom. The outboard nozzle arrangement resulted in the widest acceptable swath width, the lowest deposit across the swath, and the lowest spray recovery. The inboard nozzle arrangement resulted in a moderate swath width, the highest deposit across the swath, and the highest percent spray recovery.

For details, see the report: *Evaluation of the Boeing-Vertol 107 Helicopter and Spray System for Forest Application of Insecticide,* by Richard D. Orchard and George P. Markin (71).



Schematic showing the horizontal position of the forward and aft rotors relative to the boom.

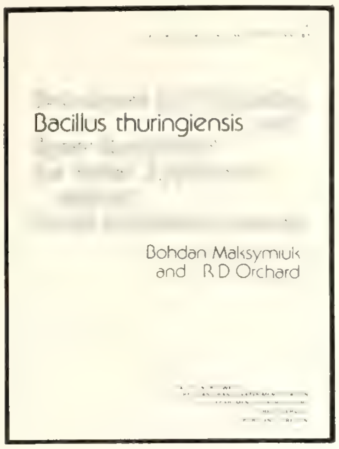
Virus Developed for Insect Control

In 1976, a naturally occurring virus was registered by the Environmental Protection Agency as a potential control method for the Douglas-fir tussock moth. Registration followed some 12 years of work at the Forest Service's Forestry Science Laboratory in Corvallis.

There, scientists conducted extensive basic studies that meant first, developing techniques to raise tussock moths in the laboratory, and identifying the natural microbial enemies (viruses and bacteria) which attack the tussock moth at various stages of its development. Scientists also established procedures for mass production and purification of the virus and demonstrated its safety to nontarget organisms.

Experiments have also been conducted to test aerial sprays of the virus, and to learn more about the natural effects of the virus on tussock moth populations in the woods.

A general article on the virus work is available (72). Additional technical notes are listed in the bibliography (73).



Bacillus thuringiensis

Bohdan Maksymiuk
and R D Orchard

Techniques for Evaluating *Bacillus thuringiensis* and Spray Equipment for Aerial Application Against Forest Defoliating Insects, by Bohdan Maksymiuk and R.D. Orchard (74)

The U.S. Forest Service has recently become interested in the possible use of the microbial insecticide *Bacillus thuringiensis* (*B.t.*) as a replacement for DDT against two major western defoliators, the Douglas-fir tussock moth and the western spruce budworm.

This paper describes techniques and presents results of a study conducted in 1972 to evaluate the performance of Dipel and Thuricide spray formulations and spray equipment for increasing the effectiveness of aerial applications to control forest defoliating insects. The Douglas-fir tussock moth and the western spruce budworm were used as test insects.

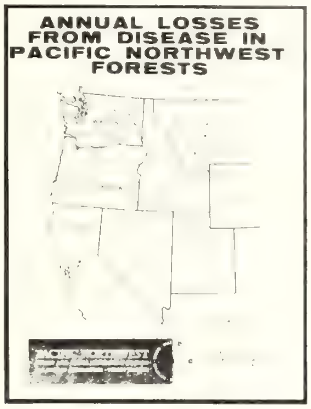
The selected formulations and spray equipment performed satisfactorily. A 100-foot swath width is recommended for field use for a small, fixed-wing aircraft equipped with a conventional spray boom and nozzles. Results indicate that *B.t.* has a high potential for control of the Douglas-fir tussock moth and the western spruce budworm.

Rotating platform for sampling aerial sprays.

For other, quite technical, publications on insect research, see reports listed in the bibliography (75).

tree diseases

impacts



ANNUAL LOSSES
FROM DISEASE IN
PACIFIC NORTHWEST
FORESTS

Annual Losses from Disease in Pacific Northwest Forests, by T.W. Childs and K.R. Shea (76)

Diseases rank with insects and fire as a major cause of damage to western forests. Annual loss from disease in Oregon and Washington was estimated at 3,133 million board feet or 403 million cubic feet in 1967.

A majority of the damage occurs west of the Cascades (234 million cubic feet), with most of the loss from heart rots. East of the Cascades, dwarf mistletoes account for more than half of the estimated annual loss of 169 million cubic feet.

The greatest damage occurs in Douglas-fir, western hemlock, true firs, and ponderosa pine. Most damaging diseases are dwarf mistletoes, root rots, and heart rots.

Researchers have found that losses are about equally divided between young and old growth. But as young stands replace old ones, the damage from heart rots will decrease, and growth-reducing diseases, such as dwarf mistletoe and root rots, will be more of a problem.

For more up-to-date information on both insect and disease pests in the Pacific Northwest, see the *Forest Pest Condition* reports published by the Pacific Northwest Region of the Forest Service. These are published every year and indicate the status of both insect and disease pests, and other damaging factors such as weather or air pollution.

Copies may be obtained by writing to:

Deputy Regional Forester
State and Private Forestry
U.S. Forest Service
P.O. Box 3623
Portland, Oregon 97208

within their ranges, they enter new clearcuts, burned-over areas, and other disturbed sites in their explorations for food, water, cover, and new areas for territorial occupation. In this way, they serve to inoculate new ground with spores of mycorrhizal fungi, thus preparing the way for seeds that fall later—either naturally or when the forester casts the seeds over the land.

Rain washes the spores into the soil where they germinate and form mycorrhizae with the rootlets of a seedling, ensuring the survival of both. Often, the seed falls on a spot where some plant is growing already, and so the seedling is at a competitive disadvantage from the start. However, if spores of a mycorrhizal fungi are there, the seedling gains a significant advantage in its competition for survival.

Dr. Trappe is project leader for the Tree Root Symbiosis Program at the Corvallis laboratory and is considered to be an international expert on truffles. In his taxonomic work he has classified and named many new species. Trappe and Trione are on joint appointments to Oregon State University through the U.S. Forest Service and have extended their research efforts into several interesting aspects of truffles. They are studying the effects of truffle fungi on tree growth, working to isolate different truffle species, and investigating the feasibility of producing them commercially as a new forest product.

end

ENTOMOLOGISTS IN ALASKA

by Thomas Michael Baugh

Two men, working more than a thousand miles apart, are involved in some of the most exciting forestry research in Alaska. Richard "Skeeter" Werner, a staff member at the Institute of Northern Forestry in Fairbanks, and John Hard, of the Forestry Sciences Laboratory in Juneau, are Forest Service entomologists. Their work involves millions of acres of forests, populated with all of the unknowns that a researcher could want.

In many ways the world of the Alaskan forests remains an enigma. For example, Werner points out that in 1975, thousands of acres of larch were defoliated in Alaska's interior region, south of Fairbanks. The insect which caused the defoliation has not been identified. This is just one of many unknowns facing researchers.

dwarf mistletoes

Getting the Jump on Dwarf Mistletoes

Dwarf mistletoes, just like the kissing kind, are parasites which get their nutrients from the tree on which they grow. In contrast to the kissing mistletoes, however, they grow on softwood trees (conifers) instead of hardwoods.

Mistletoes occur on branches or stems of their host trees. They are attached by a modified root or absorbing system inside the host tissues. Serious infections of mistletoe can result in loss of growth or deform and kill a tree.

Mistletoes are known for their unique seed dispersal system. On ripening, the berries develop an internal pressure, which cause them to explode and eject the seed upward and outward. The seeds are literally "shot" from the plant. Seeds may be propelled 30 feet or more!

Most of the Station's research on dwarf mistletoes has been on biology and ecology. New papers (not listed here) deal with biology and biological controls including discussion of the infection process and the effect of urea on infected ponderosa pine.

Occurrence of Dwarf Misteltoe in Sanitized Ponderosa Pine in South-Central Oregon, by Keith R. Shea and David K. Lewis (78)

Pruning from the bottom to control dwarf mistletoe did not work very well in a 10-year study begun in 1957 in south-central Oregon.

The study was conducted in a dog-hair thicket of ponderosa pine which was very suppressed and heavily infected with dwarf mistletoe. (There were about 5,000 trees to the acre.) The reason pruning didn't work very well is that there were just too many latent infections. You can trim off all the infected branches and still have infections in the early stages of development.

Scientists also noted that:

- The incidence of latent infections was correlated with the amount of mistletoe in the stand. Only 46 percent of the trees that looked disease-free were actually free of mistletoe infections. This was in very dense stands. In less dense stands, more trees would be disease-free.

- Most latent infections appeared within 5 years. A second thinning at that time would reduce stand infection to insignificant levels.

- Chemical eradicators might be used to stifle growth of competing trees and enable the larger ones (usually the most heavily infected) to grow faster.

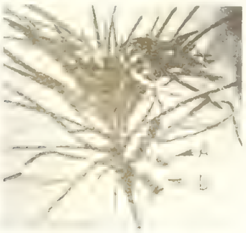
- In this study, researchers pruned from the bottom. A better system might be pruning from the top. See next discussion.

Ten years after thinning without dwarf mistletoe control, infection has increased to damaging proportions.

Dwarf Mistletoe Reduces Root Growth of Ponderosa Pine Seedlings, by Donald M. Knutson and W. Jay Toevs (77)

Dwarf mistletoes damage forest stands by causing mortality and reducing growth. This paper sheds light on one aspect of that—the effect of mistletoes on the roots of ponderosa pine seedlings.

Earlier studies (1916) had indicated that roots of heavily infected Douglas-fir, western larch, and ponderosa pine were weakened and badly decayed. But what is the effect at the seedling stage? To find out, scientists inoculated ponderosa pine seedlings with a single seed of dwarf mistletoe. At the end of 2 years, the roots of the trees were significantly shorter and lighter in weight, and fewer in number than the roots of normal seedlings. Results indicate that infected seedlings in natural stands are at a competitive disadvantage for soil moisture and nutrients and will be snuffed out at an early age.



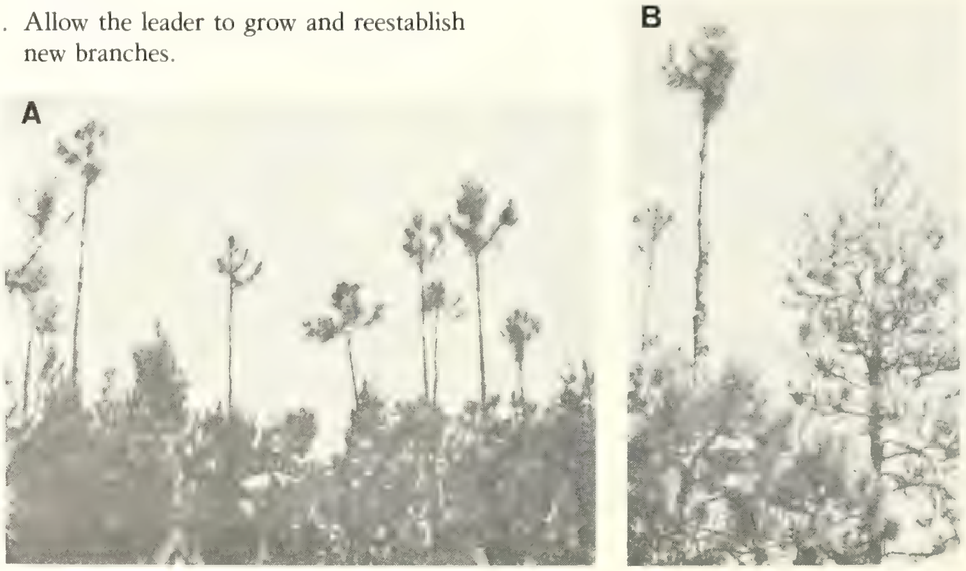
The dwarf mistletoe seed (A) and the resulting aerial shoots (B) are visible.

Dwarf Mistletoe-Infected Ponderosa Pines Survive Top-Pruning, by Donald M. Knutson (79)

Another approach to pruning for mistletoe control in ponderosa pine was dreamed up by Walt Knapp, a forester formerly with the Ochoco National Forest. Knapp and Don Knutson teamed up to test the following method—which worked:

1. Prune all the branches from the top of the tree.
2. Allow the leader to grow and reestablish new branches.
3. Then prune off the lower branches to rid the tree of all its mistletoe.

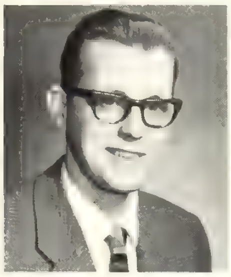
Top pruning is an additional stress on the tree, and the dryness of the site will probably affect survival. This study was done on a typical ponderosa pine site in Oregon, where precipitation is about 22 inches a year.



(A, left) Top-pruned ponderosa pines 3 years after treatment, showing new top growth and skirt foliage. (B, right) Contrast of foliage of top-pruned tree (left) and infected, unpruned tree (right).

Dwarfmistletoe Effects on Ponderosa Pine Growth and Trunk Form, by T.W. Childs and J.W. Edgren (80)

Dwarf mistletoe reduces the height growth of a tree even more than it reduces diameter growth. As a result, foresters have probably used the poor growth of the tree as an indicator of poor site quality. Actual site quality may be higher than previously thought.



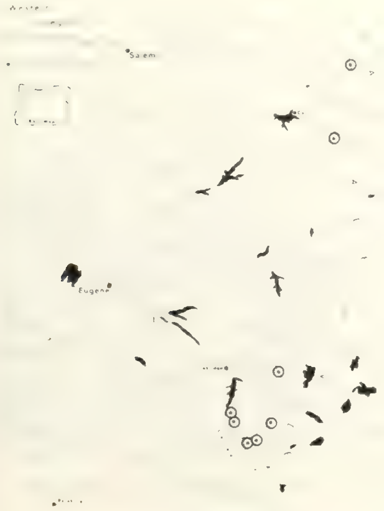
Don Knutson

Douglas-fir Dwarf Mistletoe is West of the Cascade Divide, by Robert O. Tinnin and Donald M. Knutson (81)

The potential exists for an outbreak of dwarf mistletoe in Douglas-fir on the west side of the Cascades. Until this paper, dwarf mistletoe had been reported only twice on Douglas-fir on the west side. Authors Tinnin and Knutson located an additional seven sites scattered along the west slope. The mistletoes were actively producing seed and young Douglas-fir were being infected.

Three factors are important in spread of the disease: stand density, stand composition, and fire. These appeared to be important at the infection sites on the west slope of the Cascades. The stands are relatively open and Douglas-fir is the major canopy species. Mistletoe thrives under such conditions. In addition, fire has been important at some of the west-side sites.

The researchers predict that dwarf mistletoe will become more of a problem in Douglas-fir on the west side as more and more forest stands are "opened-up" by roads, recreation areas, and other forest management activities.



Sites of infection.

Dwarf Mistletoe Infection from Residual Western Hemlock on Cutover Stands, by J.L. Stewart (82)

Dwarf mistletoe thrives where infected trees protrude above the surrounding forest canopy. Early removal of the infected "whips" is important to dwarf mistletoe control. In this study, researchers noted that a high percentage of young western hemlock (trees 15 years old) were infected within 30 feet of the whips. If the stand is less than 10 years old, however, infection should be less than 10 percent.

It makes good sense to destroy all whips when infected stands are clearcut.

Dwarf Mistletoe Seed Storage Best at Low Temperature and High Relative Humidity, by Donald M. Knutson (83)

Most foresters would like to get rid of mistletoe, but for research purposes, it is necessary to grow it in order to study it. Researchers working with dwarf mistletoe in the laboratory need to inoculate conifer hosts (small trees or branches) with mistletoe in order to conduct lengthy laboratory procedures.

Method of storing dwarf mistletoe seed at constant relative humidities.

Previously, this couldn't be done because there was no good way to store the seed year-long. It was just too short-lived. The seed can now be kept viable year-long using a technique which combines optimum temperature and humidity. The best germination occurred when seeds had been stored at 1° C., with 75 percent humidity. Germination was 94 percent at 5 months, 80 percent at 10 months, and 58 percent at 15 months.

For a similar discussion, see also: *Infection Techniques and Seedling Response to Dwarf Mistletoe,* by Donald M. Knutson (84).

Werner and his coworkers at the Institute of Northern Forestry are in a unique position to make significant contributions to knowledge of the forest ecosystem of interior Alaska. They are currently working on a series of studies about epidemics of the spear-marked black moth. During the past 2 years, this moth has raged throughout the interior, defoliating millions of acres of birch. The damage has been so extensive that the brown and golden colors of the hard-hit trees make it appear that fall exists year round.

Werner points out that there have been periodic outbreaks of defoliators for as long as records have been kept and that these insects usually hit millions of acres because of the homogeneous nature of interior timber stands.

Research on the spear-marked black moth is progressing. So far, life history studies have identified four larval stages. The pupae develop in the forest duff and emerge as adults during June. A virus, two fungi, and a bacterium have been found to kill 80 to 90 percent of the third and fourth instar larval stages, and parasites have killed up to 95 percent of the pupae. The identification of these agents holds promise for natural control methods. Werner and his colleagues at the Institute of Northern Forestry assume that hardwoods will become economically important in the future in interior Alaska, and for this reason they are accelerating their research on the insects that attack hardwood trees.

Werner emphasizes the important natural role insects play in the maintenance of the forest. Insects, for instance, add to nutrient cycles. Leaf parts and waste drop to the forest floor by the ton, contributing to the slowly decomposing mass of the forest duff and the nutrient cycle. In addition, birds, yellow jackets, and hornets feed on the moths and act as natural controls.

Until recently, the spruce bark beetle had received the most study in interior Alaska. Entomologists now feel that proper management of forests will help counteract the destructive effects of this forest pest. They have found that the beetle populations expand in areas where untreated slash remains on the ground. Treatments of slash and other residues will significantly reduce the beetle problem.

white pine blister rust

Spread of White Pine Blister Rust from *Ribes* to Sugar Pine in California and Oregon, by James W. Kimmey and Willis W. Wagener (85)

This 71-page pamphlet was published by USDA in 1961, but it is still an excellent summary of the blister rust problem and reasons for its spread.

Blister rust is a severe disease of white pines the world over. It is caused by the fungus *Cronartium ribicola* which spreads in pine forests by way of an alternate host—the wild gooseberry or *Ribes* bush. It attacks all five needle pines, and is especially damaging to sugar pine. In fact, foresters have all but given up on sugar pine as a species for commercial timber production because of the disease.

Blister rust was once controlled by eradicating the gooseberry bushes. Eventually this was judged to be ineffective, or at least too costly, and is no longer being done.

Field tests were conducted between 1935 and 1950 at two locations in southern Oregon and four in California to determine just how blister rust spreads. A total of 56 tests were made on 21 plots. Spread of infections from these sites was erratic. Researchers found that blister rust spreads only under conditions that are favorable to survival of the fungus—generally with adequate moisture being the most important condition. Forests are especially vulnerable to attack and spread of the fungus when weather conditions are humid, where dewfall is heavy at night, or near places of higher than average soil moisture—as along meadows, stream bottoms, or other wet places.

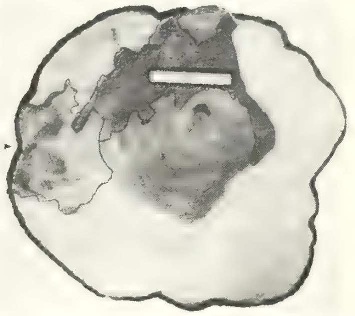
Decay Following Logging Injury to Western Hemlock, Sitka Spruce, and True Firs, by Ernest Wright and Leo A. Isaac (87)

Have you ever run an autopsy (treetopsy?) on a forest tree? That's what two former PNW researchers did to learn more about the diseases that sometimes occur when trees are injured during logging.

The scientists studied the frequency and amount of decay associated with logging injury on western hemlock, Sitka spruce, and the true firs—grand fir and Pacific silver fir. What they found was—in scientific terms—about as complicated as the physicians' names for a liver ailment or heart conditions—diseases like *Fomes annosus, F. pinicola, Armillaria mellea, Ganoderma oregonese,* and some they couldn't identify.

Most important (by common name) were *Fomes* root and butt rot, stereum rots, and brown crumbly rot. All in all 20 different fungi-causing rot in western hemlock were identified, 11 in Sitka spruce, and 8 in the true firs. Trees were also subject to sunscald, windfall, and breakage.

The publication provides information on the probability of occurrence of decay and its rate of spread after logging injury. Data can be used to estimate how much logging damage can be tolerated in a timber stand and to decide what cutting practices will keep injury within allowable limits.



Sunscald damage in a western hemlock. At left (arrow), the cambium was killed by sunscald. Logging scar (above ruler) was invaded by Fomes annosus.

Eliminating Blister Rust Cankers From Sugar Pine by Pruning, by G.L. Hayes and William I. Stein (86)

This publication results from a study conducted about 1952 in the South Umpqua Experimental Forest. The study was a special effort to see if blister rust infections could be removed from understory sugar pine in a two-story forest—one with well-stocked patches of vigorous young sugar pine coming up beneath deteriorating old-growth. Unfortunately, the sugar pine was infected with blister rust! Researchers wanted to save the advance growth rather than cut and replant. So they tried pruning the young trees to get rid of the blister rust.

In this case it worked. Ninety-five percent or more of the visible blister rust cankers were removed. Costs were reasonable. It would probably work again under similar conditions.

Additional publications on blister rust may be obtained from the Intermountain Forest and Range Experiment Station: 507 25th Street, Ogden, Utah 84401.

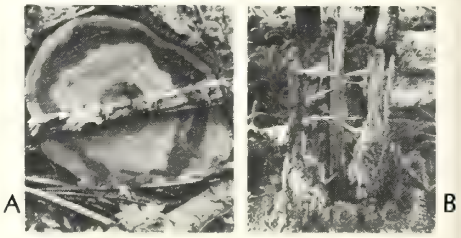
phellinus (poria) weii

Laminated Root Rot of Douglas-fir in Western Oregon and Washington, by T.W. Childs (88)

Laminated root rot, caused by the fungus *Poria weirii,* damages many conifers in the Pacific Northwest, especially Douglas-fir west of the Cascade Range in Washington and Oregon. It attacks trees of all ages but is most destructive in stands from about 25 to 125 years old.

Poria not only damages trees, it kills them. The disease spreads through the roots of the trees, often moving from roots of infected older trees to roots of young trees. Young trees that are infected seldom live long enough to have their growth reduced. In old-growth stands, where trees are killed more slowly, the disease is less common and decay usually extends only a few feet into butt logs.

It is not yet possible to control laminated root rot, but its economic impact can be reduced by the management practices recommended. This paper summarizes results of research during the past twenty years (published in 1970).



A, Cross section of Douglas-fir base showing incipient and typical decay caused by Poria weirii; *B, base of tree killed many years ago, showing persistent branch bases.*

Invasion of Freshly Cut Douglas-fir Stumps by *Poria Weirii,* by Earl E. Nelson (89)

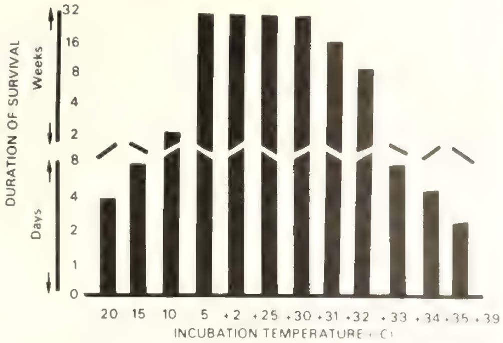
Research has already shown that *Poria* can infect trunk wounds of conifers. If this could happen on stumps, it could greatly accelerate spread of the disease in thinned Douglas-fir plantations. A study was begun in 1967 to learn more about this possibility.

From results of this study, it looks as though spores of the fungus may not penetrate freshly-cut stumps. But the researchers were able to consistently produce the disease by placing the mycelia (vegetative growth) of the fungus on stump surfaces. Under these conditions, the mycelia of *P. weirii* can grow downward at least 12 inches a year—fast enough to enter main roots of thinned tree stumps in a year's time.

Thermal Tolerance of *Poria weirii*, by E.E. Nelson and H. Fay (90)

Soil temperature is probably not a direct factor in determining the survival of *Poria weirii*. In laboratory studies, *P. weirii* survived 32 weeks at temperatures between −5 and +30° C. Although extreme hot or cold can be lethal to the *Poria*, these temperatures are not common deep in the soil where the fungus thrives.

Future research will concentrate on the effects of temperature on *P. weirii*-soil microbiological relationships rather than on effects on the fungus itself.



Survival of Poria weirii in alder sections.

Earl Nelson

Observations on the Formation of Zone Lines in Wood by *Poria Weirii*, by E.E. Nelson (91)

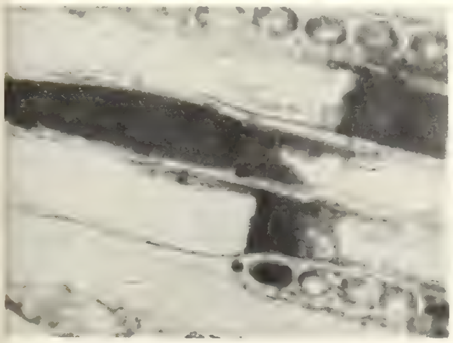
A fairly technical, but fascinating, paper that describes the formation of zone lines in wood infected by *P. weirii*. Under the microscope, zone lines appear as dark lines in cross sections of wood. Although they look like lines, they actually envelop the active fungal colony. They apparently protect the fungus from drought and serve as a barrier to keep antagonistic microorganisms from crossing the lines.

Research may help eventually in developing biological controls for the disease. So far, Nelson has found the following:

1. Zone lines can be formed in 30 days or less under temperature conditions normal in forest soils during most of the year.

2. The protective zone lines will not form in buried wood at temperatures above 15° C.

3. Where microbial competition is absent and other factors are favorable for *P. weirii*, it does not form zone lines.



Microscopic section showing composition of P. weirii zone line.

Estimating Spread of *Poria weirii* in a High-Elevation, Mixed Conifer Stand, by E.E. Nelson and T. Hartman (92)

Aerial photographs can be used to measure the rate of spread of *Poria weirii* in high-elevation forests. Aerial photographs used for this study were taken in 1946 and 1972 in the vicinity of Waldo Lake in the Willamette National Forest. The forest is dominated by an overstory of mountain hemlock, a species very susceptible to *P. weirii*.

The infection centers show up on aerial photographs as irregular rings that are lighter in color than the surrounding forest, and are easy to measure.

During the 26 years between the two sets of photographs, the disease spread at the rate of about 13½ inches per year (radius of the infection).

Examination of aerial photographs can help in making management decisions where *Poria* is a problem. For example, planners would want to avoid putting campgrounds near *Poria* centers because of the increased danger of falling trees.

Survial of *Poria weirii* in Wood Buried in Urea-Amended Forest Soil, by E.E. Nelson (93)

Studies indicate that urea may affect survival of *Poria weirii*. *Poria* infections failed to survive in wood cubes that had been buried in soil mixed with urea.

What happened (see also item 90) apparently was that the urea stimulated antagonistic microflora which invaded the *Poria*-colonized cubes before zone lines (adequate defenses) could be formed. The fungus did not survive in cubes without zone lines.

A common forest fertilizer, urea is high in Nitrogen (46 percent). Earlier work had shown that both NO_3 and NH_4 forms of nitrogen are effective in reducing *P. weirii* under laboratory conditions.

The situation is different in southeast Alaska. There, the research emphasis is on the black-headed budworm and the hemlock sawfly. Between 1950 and 1955, the budworm was responsible for the defoliation of 9 to 10 million acres of spruce forest in southeast Alaska.

John Hard, entomologist with the Forestry Sciences Laboratory in Juneau, says that the focus of the budworm and sawfly research has been the biology and population ecology of the two species. The most significant effect of both defoliators is reduction in the growth of affected trees and some top kill. In several cases, all parts of the tree were killed.

Hard points to several factors that help control these forest pests. For example, the sawfly and budworm in southeast Alaska are living near the northern limit of their range where conditions are less than ideal. Hard feels there may be a relationship between weather and insect outbreaks. He and Bill Farr, a research forester, are analyzing weather data from 50 to 60 stations in coastal Alaska. The weather data will be used to establish climatic zones to see how these zones compare with the areas where the risk of insect attack is high.

The main research effort involves identification of natural controls and their interaction. Hard says that parasites and fungi, acting together with the cool, moist climate of southeast Alaska, usually control outbreaks naturally before damage becomes extensive in virgin stands.

Most Alaskan timber is harvested from the hemlock and Sitka spruce forests of the southeastern panhandle. The rate of timber harvest has increased since the 1950's. Any time an environment is modified, the risk of problems, such as insect outbreaks, is increased. Hard feels it is highly probable that chemical control will become more necessary as young, managed forests replace the old growth. Environmentally safe chemicals such as Orthene, Dylox, and Lannate, have been tested and look promising.

The work of Werner, Hard, and other entomologists is filling in the gaps in man's knowledge of the forest ecosystems of Alaska. These research results are helping to insure productive resource management for the land of the midnight sun.

end

next "insight" page 133

Effect of Urea on *Poria weirii* and Soil Microbes in an Artificial System, by Earl E. Nelson (94)

The ability of *Poria weirii* to survive for many years in decaying root systems makes this destructive root pathogen extremely difficult to control in Pacific Northwest coniferous forests. Competing soil microorganisims replace this root-infecting fungus in decaying root systems but generally not before new disease centers develop in the regenerating forest. Centers thus formed enlarge with root to root spread as a stand develops. Opportunities for control of this disease appear best at final harvest when heavy equipment is present, mobility on the site is least restricted, harvest and reforestation options are available, and soil treatments such as organic amendments or chemicals can be applied.

Colony of P. weirii growing on surface of soil.

Application of N fertilizer seems to be a promising control measure. Nelson found that application of urea at the rate of 674kgNha^{-1} resulted in a dramatic reduction in survival of *P. weirii* in buried wood. This study relates rate of application of urea to microbial activity and consequent suppression of *P. weirii* in buried wood.

Urea added to soil in containers indirectly reduced survivial of *P. weirii* in buried stem sections by regulating populations of soil microorganisms. After 8 weeks a noted antagonistic competitor, *Trichoderma,* began to increase. At the same time survival of *P. weirii* was reduced. After 32 weeks, *P. weirii* survived only where urea was not added. *Trichoderma* was found in stem sections no longer containing living *P. weirii.*

The possibility of this disease control system working under natural conditions is now being tested.

Epiphytology of a Needle Cast Fungus, *Lophodermella morbida,* in Ponderosa Pine Plantations in Western Oregon, by George M. Harvey (95)

Lophodermella morbida, a recently described needle cast fungus, is epiphytotic in plantations of ponderosa pine in the Douglas-fir forest type above 2,500 ft. on the western slope of the Cascade Range in southwestern Oregon. Mature ascospores are discharged during periods of rain from early June through mid-July. Only foliage recently emerged from the fascicle sheath becomes infected. Infected foliage drops from the tree by late summer of the next year. Growth of repeatedly infected trees is reduced; however, mortality appears to be slight.

Probably *L. morbida* is a native fungus catapulted to prominence on a susceptible host planted on unfavorable sites under climatic conditions favoring the disease. Ponderosa pine should no longer be planted on these sites. Such sites especially include ridgetops and natural basins where clouds tend to linger after a general storm. The risk to ponderosa pine stands east of the Cascade crest appears minimal because of limited early summer moisture and cold winter temperatures.

insect and disease-bibliography

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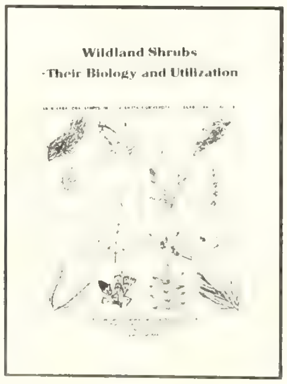


Wildland Shrubs—Their Biology and Utilization, Proceedings of a Symposium, July 1971 (1)

A collection of 48 papers on various aspects of wildland shrubs—from genetics to uses, distribution, physiology, nutrition, regeneration, and the future of shrubs in arid lands. (Available from the Intermountain Forest and Range Experiment Station, 507 25th Street, Ogden, Utah 84401.)

One chapter in the book is by a PNW Experiment Station scientist, George A. Garrison, who discusses "Carbohydrate reserves and response to use." Carbohydrates are important to plants because that is their major source of energy and "raw" material. According to Garrison, "These basic organic substances are the available or nonstructural carbohydrates such as sugars, fructosans, dextrins, and starch which are mobilizable and available within the plant for its nutrition and development."

Seasonal levels of carbohydrate reserves in a key forage species provide primary implications of best dates and systems of grazing to avoid degradation of that species' capacity to sustain itself.

For another report on carbohydrates in range plants, see a paper by B.R. McConnell and G.A. Garrison on *Seasonal Variations of Available Carbohydrates in Bitterbrush* (2). Also see a plant food reserve study by Garrison on elk sedge and wheatgrass titled, *A Preliminary Study of Response of Plant Reserves to Systems and Intensities of Grazing on Mountain Rangeland in Northwest USA* (3).

Seasonal Trends in Plant Nutrients Studied

Livestock and game managers are increasingly aware of the nutritional aspects of range management. An adequate diet for range animals is essential for the efficient production of animal products.

Deficiencies in protein, phosphorus, and carotene (vitamin A) are common on western ranges and have led to studies on nutritional values of forage plants. Such information can be used to estimate the seasonal adequacy of animal diets and is needed in order to adopt sound management practices.

A limited number of such studies have been undertaken in Oregon by scientists of the Pacific Northwest Forest and Range Experiment Station and Oregon State University. The Silver Lake sagebrush-grass range, 80 miles south of Bend, is important from the standpoint of big game use and livestock production. Extensive research in livestock and big game management has been conducted there. Studies have included effects of big sagebrush (*Artemisia tridentata*) in deer diets and determination of crude protein levels in native grass and shrub species during winter and early spring. This study was developed to:

1. Define seasonal trends for the crude protein, fiber, and fat (ether extract), moisture, ash (total mineral matter), calcium, phosphorus, and apparent digestibility in selected forage species; and
2. Determine if these trends vary between ecologically different vegetation types.

For details, see *Seasonal Trends in the Nutritive Content of Important Range Forage Species Near Silver Lake, Oregon,* by O. Eugene Hickman (4).

Ecology of Curlleaf Mountain-Mahogany in Eastern Oregon and Adjacent Areas, by John Edward Dealy (5)

Curlleaf mountain-mahogany, a small, hardwood evergreen tree, was studied to provide information on germination and initial seedling growth characteristics, and the tree's relationship to its environment and associated vegetation.

This is a Ph.D. thesis available in microfilm or Xerography from Xerox University Microfilms, Dissertation Copies, P.O. Box 1764, Ann Arbor, Michigan 48106. Charge is: $7.50 academic, $10.00 other.

Ed Dealy

Relationship of Root Length to Stem Diameter in Curlleaf Mountain-Mahogany, by Pamela S. Talley and J. Edward Dealy (6)

Measurements were made of root lengths and stem diameters on 24 curlleaf mountain-mahogany seedlings 112 days after germination. Plants with the longest root systems had the largest stem diameters, indicating general plant vigor. Selection of seedlings with larger stem diameters for use in out-planting or research may increase rate of survival.

Some Autecological Characteristics of Elk Sedge, by G.O. Klock (7)

Elk sedge, a grasslike plant with extensive fibrous roots and high drought tolerance, may be one of the most important native, herbaceous forage species on national forest lands of Oregon and Washington. Quick establishment of this plant on depleted grazing lands would be desirable for erosion control.

However, there are no techniques available now for artificial regeneration of this species. Preliminary work indicates that "cores" taken from clones of the plant can be transplanted successfully. Elk sedge also showed positive response to nitrogen and potassium fertilization.

Soil Properties and Nutrient Availability in Tarweed Communities of Central Washington, by Arthur R. Tiedemann (8)

High elevation grasslands on basalt-capped plateaus dominated by Columbia needlegrass are important summer range for livestock and wildlife in north central Washington. These plateaus are also vital sources of water.

But a prevalent problem on these grasslands is a series of abrupt breaks in the grassland vegetation. These areas tend to be dominated by cluster tarweed, a species not palatable to wildlife or livestock.

This study explores the reasons for the change in vegetation, focusing on the soil nutrient levels, nutrient availability in the soil, and soil physical properties. Results indicate a lower nutrient capital and availability of nitrogen and sulphur, and lower capital of exchangeable manganese in the tarweed communities, and suggest the need for adding these nutrients to the soil.

How much browsing on shrubs by big game and livestock constitutes proper use? This question was not formulated or studied as early as questions about proper use on grasses. Also, the existing knowledge of livestock and big game preferences for different shrubs was not always the high-interest item that it is today.

Research on the level of tolerance that shrubs have to twig removal was performed for several Northwest shrubs and was reported by Garrison in an article entitled, *Effects of Clipping on Some Range Shrubs* (9). The information in this article and a companion item on *Annual Fluctuation in Production of Some Eastern Oregon and Washington Shrubs* (10) will prevent some bad generalizing that all shrubs on all sites can withstand 50 percent use in any year.

A summary of information as to which animals prefer which shrubs for browsing is tucked away in the back of a very easy to use shrub identifier by Hayes and Garrison, *Key to Important Woody Plants of Eastern Oregon and Eastern Washington* (11). You should be able to find this popular little book in either your municipal or college library.

Range Ecosystem Research, The Challenge of Change, a brochure, September 1970 (12)

One characteristic of our times is change, and change brings with it challenges, opportunities, and problems. As we have looked forward to the 1970's, we have taken a new look at the nation's rangelands and their importance to all segments of society. Half of the United States is rangeland, and as population, industrialization, and urbanization increase, rangeland's role expands. The economy of many localities and regions depends on range resources.

In meeting the challenge of the 1970's and adapting to changes in society's needs, what is the best way to proceed with research on the problems of managing, conserving, and using rangelands?

This publication outlines the direction the Forest Service has taken with rangeland research and explains the underlying philosophy. That direction is based on the findings of a committee appointed in 1968 by the Chief of the Forest Service to: (1) make a critical review of range research; (2) consider society's changing needs for range resources; and (3) develop a comprehensive basis for research programs to meet those needs.

FISHERIES BIOLOGIST IN ALASKA

by Louise Parker

"Look, those are Dollies," Art Bloom said as he stepped off the trail to scan the adjacent stream. A swarm of Dolly Varden char wove dark shadows in the cold, clear water.

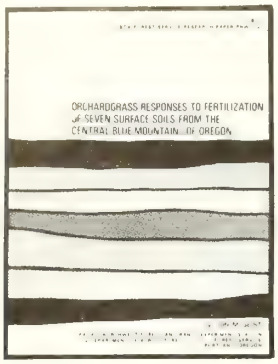
"These fish will spend several years here, growing to around 8 inches in length before they head for the sea," Art explained. The stream along which he walked is a very small tributary of the Kadashan River, which flows through a beautiful, remote part of Chichagof Island in southeast Alaska's Tongass National Forest. In the summer, the river is filled with salmon coming upstream to spawn. In 1973, close to 150,000 pinks (humpback) and chums (dog) salmon were counted upstream in the weirs.

The Kadashan and its tributaries are typical of much of the habitat of salmon and trout in southeast Alaska. This makes it an ideal study area for Art, a fisheries biologist with the U.S. Forest Service's Forestry Sciences Laboratory in Juneau.

Art and his wife, Joy, have spent several years at Kadashan Bay where Art is conducting research for the Forest Service. His job is to evaluate the habitat requirements of the fish which spawn in fresh water tributaries to the Kadashan River. This includes coho (silver) salmon, Dolly Varden, and rainbow and cutthroat trout. Six of the smaller tributaries to the Kadashan have been selected as study areas.

"There—under the bank. Those are coho," Art said, as he picked his way through the

orchard grass



ORCHARDGRASS RESPONSES TO FERTILIZATION OF SEVEN SURFACE SOILS FROM THE CENTRAL BLUE MOUNTAINS OF OREGON

Orchardgrass Responses to Fertilization of Seven Surface Soils From the Central Blue Mountains of Oregon, by Jon M. Geist (13)

This study was conducted to determine the major nutrient deficiencies in seven soils in the Blue Mountains of Oregon. Chemical analysis indicated that there were large differences among the soils in both chemical and physical properties.

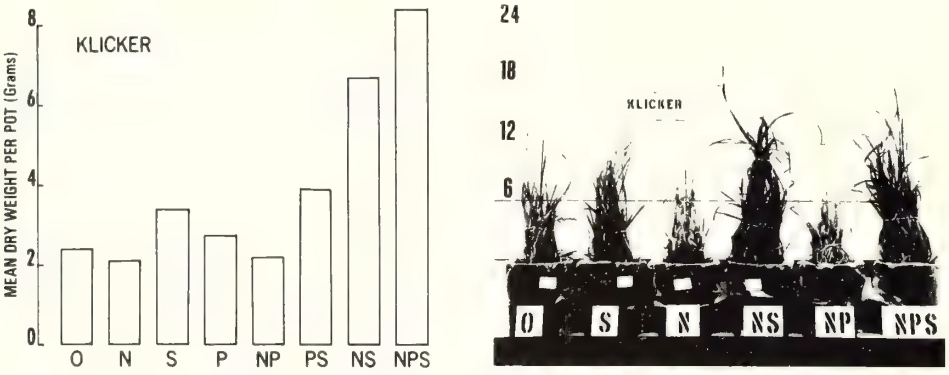
Greenhouse tests in which orchardgrass was grown in the soils with various fertilizers added indicated other results:

- In most soils, both nitrogen and sulfur were necessary in order to get maximum growth increases from either element.

- For two soils (both grassland soils), the maximum benefit from fertilizer was possible only by adding phosphorus with nitrogen and sulfur.

- Volcanic-ash-derived soils had the highest response to fertilization and should give the greatest economic return if site and climatic factors are not otherwise limiting.

For another paper on response of orchardgrass to fertilization, see also, *Response of Orchardgrass to Sulphur-Coated Urea,* by G.O. Klock, J.M. Geist, and A.R. Tiedemann (14).



Mean dry matter produced by each fertilizer treatment combination on the Klicker soil. The photograph illustrates plant growth with certain treatments.

pocket gopher

The Dalles Pocket Gopher and Its Influence on Forage Production of Oregon Mountain Meadows, by A.W. Moore and E.H. Reid (15)

Pocket gophers are not something you keep in your pocket. In fact, range managers would probably just as soon not keep them at all. Yet they are found in many places throughout western range lands and are especially common on meadows in the mountainous areas of the West. As a result, some meadows are seriously depleted, with grazing capacities as low as 0.1 or less animal-unit month per acre.

This paper (1951) is the result of a cooperative study by the Fish and Wildlife Service and the Forest Service from 1931 through 1948. The life history of the pocket gopher was studied, as well as its effect on the composition, density, and value of mountain meadow vegetation.

Results of the study indicate that gopher control is necessary to get satisfactory improvement of infested mountain meadows that are in poor condition. If ranges are in fair condition, however, control may not be necessary. In that case, the main value of control would be to make the additional forage available to livestock or to permit more rapid restoration of the range.

Gophers and Range Grass

It is no secret that gophers can destroy rangeland cover in a big way. Apparently they prefer to eat those plants with underground bulbs or fleshy roots. But they will also munch on the root crown of an occasional clump of grass, or new tender shoots of grass.

When unprotected from gophers, new stands of tall oatgrass with bulb-like stem bases were the first to be damaged and suffered most. Wheatgrass was less attractive.

Researchers also found that gophers were less likely to damage bunchgrass seedings if the drill rows were at a narrow spacing (12'') rather than a wide spacing (36''). The latter permitted an invasion of fleshy rooted weeds and encouraged gopher tunneling as the animals searched for tap-rooted herbs. This information should discourage the practice of wide drill-row spacing. In the old system, bunchgrass was seeded at wide intervals, with the range manager attempting to depend on natural reseeding to fill in the stand between drill rows.

Thorough seedbed preparation for new grass seedings aids distruction of fleshy rooted weeds and makes new grass planting sites less attractive to gophers than weedy sites.

Results are reported in *Relation of The Dalles Pocket Gopher to Establishment and Maintenance of Range Grass Plantings,* by George A. Garrison and A.W. Moore (16).

bitterbrush

Some Effects of Grazing Intensity on Bitterbrush Dispersion, by Burt R. McConnell and Justin G. Smith (17)

Three fence-line comparisons were made to determine the effect of grazing intensity on the density and dispersion of bitterbrush in a uniform habitat. Bitterbrush density was reduced by heavy grazing but was not affected by moderate use.

The large increases in mean area per plant that occurred under heavy grazing did not alter the overall form of random dispersion found under all grazing treatments.

Influence of Grazing and Age on Crown Characteristics in Bitterbrush, by Burt R. McConnell and Justin G. Smith (18)

Changes in average crown diameter and percentage of dead crown were related to bitterbrush age on moderately and heavily grazed ranges. There was a significant difference in average crown diameter under the two levels of grazing intensity, but the difference between percentages of dead crown area was not significant.

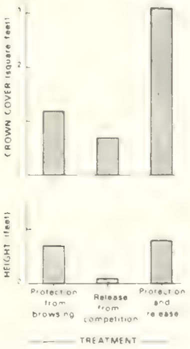
Effect of Logging on Bitterbrush

The effect of logging and slash disposal on he bitterbrush understory in a lodgepole pine forest has been studied in central Oregon. Soils were moderately to heavily disturbed on 75 percent of the area, and bitterbrush crown cover was reduced by 71 percent. Most of the damage resulted from slash disposal. Despite extensive damage, shrubs quickly responded to more favorable growing conditions in the postlogging environment. Twig growth doubled and large numbers of seedlings were established on disturbed soils.

Results are from, *Initial Response of Bitterbrush to Disturbance by Logging and Slash Disposal in a Lodgepole Pine Forest,* by Paul J. Edgerton, Burt R. McConnell, and Justin G. Smith (19).

Survival and Growth of Bitterbrush on the Silver Lake Deer Winter Range in Central Oregon, by J. Edward Dealy (20)

This report (1970) presents results of the first 2 years of a study on survival of planted bitterbrush and its response to browsing protection and release from competing vegetation in central Oregon. After 2 years, researchers found that bitterbrush responded better to protection from browsing than from elimination of plant competition. Also, the additional growth tended to be in crown size rather than in plant height.



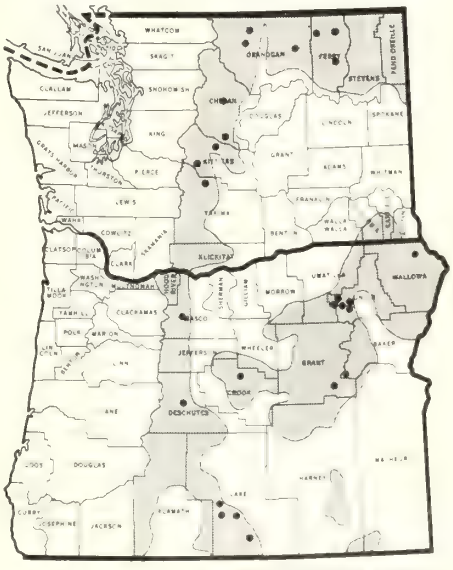
Average response per plant of an established antelope bitterbrush planting after 2 years of protection from deer browsing, vegetation competition, and the two combined.

range rehabilitation

Seeding Summer Ranges in Eastern Oregon and Washington, by Robert S. Rummell and Clark E. Holscher (21)

Range seeding, as an adjunct to good range management, is needed to increase the productivity of eastern Oregon and eastern Washington summer ranges. On about 600,000 acres, now yielding only a small percentage of their potential forage production, seeding is the only practicable way to reestablish a stable vegetative cover and increase the forage supply within a reasonable length of time.

To find successful ways for seeding summer ranges, the Forest Service has tested approximately 150 forage species and strains on many experimental areas under numerous conditions and methods of planting. In addition, many other seedings made by ranchers and federal land administrators have been studied, and information from the Soil Conservation Service and state agricultural experiment stations has been drawn on where pertinent. The results are the basis of recommendations reported in this bulletin.



Summer range areas in eastern Oregon and eastern Washington

Sagebrush Control on Rangelands, by Joseph F. Pechanec, A. Perry Plummer, Joseph H. Robertson, and A.C. Hull, Jr. (22)

According to the authors, sagebrush is not the most desirable range plant on western range lands. Where range grazing is the preferred use, they advocate getting rid of the sagebrush and restoring forage plants through natural or artificial seeding.

"Innumerable examples have demonstrated that sagebrush eradication can more than repay its cost on many ranges in the West; double to 25 times greater grazing capacities have been obtained."

The authors discuss where and when to control sagebrush, and give some practical guidelines about how: by burning or use of herbicides, plowing or disking, anchor chaining, harrowing, cutting, beating, shredding, and some other methods.

brush along the creek. Coho prefer slow-moving water and often hide in pools where the bank has been undercut. In the cold streams of Alaska coho remain in fresh water for 2 to 3 years before moving to the ocean as smolts. Dolly Varden, on the other hand, are bottom feeders and prefer riffles and fast-moving water where insects abound. Art grabbed a mosquito from his jacket and tossed it into the water. It was quickly gobbled up by a young coho.

For a long time, Dolly Varden were considered undesirable because the adults feed on salmon eggs, and salmon are one of Alaska's principal commercial fish. Dollies were occasionally poisoned, and there was even a bounty for a while. But biologists now know that Dollies feed mostly on loose eggs which wash away in the current during spawning. They present little threat to the salmon. Too, fisheries is an important part of the tourist trade. Each year more and more people vacation in Alaska. By 1980, some 325,000 visitors are expected each year. Many come solely for hunting and fishing. In Alaska, the sport and commercial fishing industry is a multimillion dollar business. And Dolly Varden are a "good eating," popular sport fish.

Along the trail Art pointed to evidence of timber cutting in the flat land at the upper end of the estuary. A portion of the forest was logged in the early 1950's. Mostly it was high graded, rather than clearcut as is the practice today. The timber company took just the biggest and best hemlock and spruce, and left the rest. In southeast Alaska, good timber regions like this may have been "high graded" several times. At Kadashan Bay, the logs were skidded out by tractor, a practice foresters today believe causes the most disturbance, especially to stream channels.

Twenty years after logging, the land is green once again. Only a few stumps, skidroads, and patches of alder show where logging occurred. But very few hemlock and spruce have come back. Mostly it's pole-sized alder along old skidroads. It takes a long time for the conifers to come back naturally in this bottom-land country.

One of the skidroads at Kadashan indicates the poor logging practices of the past. It becomes a watercourse when the stream is in flood stage. Water in this channel disappears in the summer, leaving young coho and trout trapped in small ponds. They die when the water dries up.

Standley Range, a brochure, July 1976 (23)

A brochure describes the Standley Range in the Wallowa Mountains of eastern Oregon and its place in the history of research and management of national forest rangelands in the western United States. It was in these subalpine grasslands in the early 1900's that Dr. Arthur W. Sampson conducted early range studies and developed ecologically sound principles of livestock management on mountain rangelands.

Sampson's plant and range ecology studies, conducted between 1907 and 1911, contributed greatly to the infant science of range management. Thanks in part to his work, the subalpine grasslands of the Wallowas have been restored and are now able to support small herds of sheep in the summer.

forested range

Management of Conifer Woodland Grazing Resources for Cattle, Deer, and Elk, by Jon M. Skovlin and Robert W. Harris (24)

Deferred-rotation grazing in the open forest was the only management treatment which resulted in significant improvement in herbage production. There was no real difference between levels and systems on grassy openings. In the forest, however, herbage production was definitely improved by reducing cattle pressure and employing a deferred-rotation system.

A close relation exists between cattle management and use by deer and elk on these woodland ranges. Elk are especially sensitive to grazing pressure by cattle, perhaps owing to the presence or absence of ungrazed forage. Although deer and elk accounted for about one-fourth of the forage used, they did not make much use of forage important to cattle.

The low rate of stocking provided gains in elk sedge production, and least interference with food and habitat preferences of deer and elk. Deferred-rotation grazing provided for maintenance and improvement of elk sedge, the most abundant forage species for both elk and cattle.

Some Effects of Livestock Grazing on Ponderosa Pine Forest and Range in Central Washington, by Robert S. Rummel (25)

A study of ungrazed Meeks Table and grazed Devils Table in central Washington provided evidence that parts of the virgin ponderosa pine forest contained dense mats of herbaceous understory vegetation and sparse stands of tree reproduction. Pinegrass dominated and elk sedge was a minor part of the understory virgin flora.

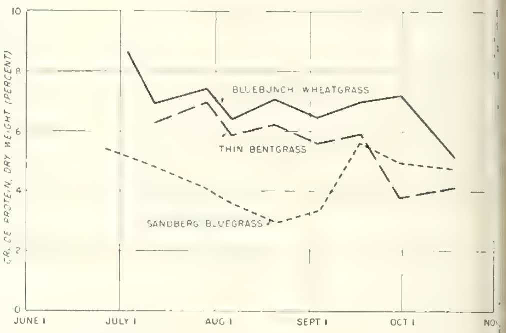
Densities of herbaceous understory vegetation on ungrazed Meeks Table were 183 percent to 254 percent of the densities on grazed Devils Table. Herbage yields of pinegrass were strikingly different between the two tables. Pinegrass beneath open ponderosa pine produced 850 pounds of air-dry herbage per acre on Meeks Table compared to only 240 pounds on Devils Table. While the timber overstories on the two tables were similar, Meeks Table had only a very few small trees but Devils Table had 3,291 small trees per acre.

The high density of herbaceous understory vegetation on Meeks Table contributed substantially to the deficiency of advance tree reproduction. Heavy grazing of the herbaceous understory vegetation, rather than exclusion of fire, appeared to be the prime factor in explaining the dense advance tree reproduction on Devils Table.

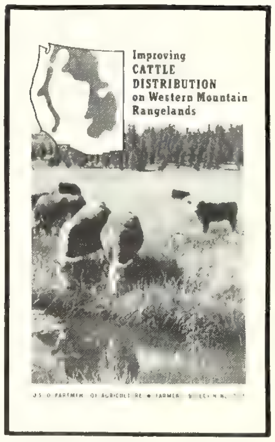
Forage Utilization on Summer Cattle Ranges in Eastern Oregon, by G.D. Pickford (27)

This USDA circular (1948) presents the results of a 2-year study at the Starkey Experimental Range in eastern Oregon. The study was designed to learn more about the best grazing regimes for various forage plant and range types in the summer ranges of eastern Oregon. Results apply to the open mixed-conifer type of the Pacific Northwest, but many of the principles can be used in the management of mountainous range lands throughout the West.

The values of various summer-range types are discussed:
bunchgrass
dry meadows
pine-bunchgrass
pine-grass-elk sedge.



Crude-protein content of important grasses of the untimbered-range type, 1941.



Improving Cattle Distribution on Western Mountain Rangelands, by Jon M. Skovlin (26)

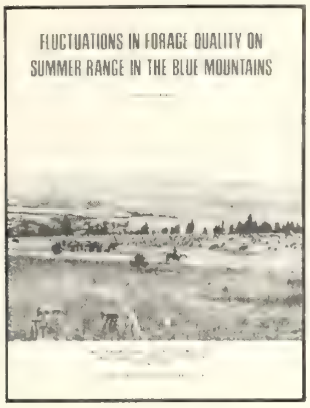
Many ranchers lose valuable forage from uneven cattle distribution. Left to their natural inclinations, cattle tend to graze the easy acres while forage is underused on less accessible range. Unless these habits can be overcome, forage yield from high-producing areas will continue to diminish while usable forage on the less accessible range is wasted.

Distribution problems are aggravated for a cattleman who depends on mountain range of intermingled forest, brush and grassland. This range can be properly stocked as a whole, yet be severely overutilized in some places and unused in others.

Improving distribution enlarges the area of properly grazed range. More forage is taken from unused and lightly used range, and grazing pressure is reduced on habitually overused range.

Benefits to the rancher from better distribution are more complete utilization of available forage and faster recovery of depleted range. Heavier cattle, more calves, and more effective use of salt, water, and supplemental feed can result.

Jon Skovlin


FLUCTUATIONS IN FORAGE QUALITY ON SUMMER RANGE IN THE BLUE MOUNTAINS

Fluctuations in Forage Quality on Summer Range in the Blue Mountains, by Jon M. Skovlin (28)

Rangelands in the Blue Mountains of eastern Oregon and Washington provide 4 to 5 months of grazing for about 100,000 cattle. They also furnish 3 to 4 months of forage for nearly as many sheep. Big-game census and harvest figures indicate these same ranges carry an estimated 200,000 mule deer and about 65,000 elk for 6 to 8 months. The importance of this forage resource is apparent.

Although these native ranges have been grazed by livestock for over 100 years, little is known about their seasonal forage quality. Information on range plant values is needed to aid managers in getting full benefit from the forage supply through improved systems and seasons of grazing. This knowledge will also help ranchers in deciding when to change grazing practices or to market animals. To the big-game manager, the level of late-season forage quality suggests the condition of deer and elk for winter.

This paper combines unpublished research with several reported studies in an attempt to assess overall range forage value in the Blue Mountains. Much of the work has been done on the Starkey Experimental Forest and Range. It has been a field proving ground for grazing research on forest and related ranges for over 25 years.

Effects of Cattle Grazing Methods on Ponderosa Pine-Bunchgrass Range in the Pacific Northwest, by J.M. Skovlin, R.W. Harris, G.S. Strickler, and G.A. Garrison (29)

Reports results of an 11-year study of plant and animal responses to grazing in the pine-bunchgrass range of eastern Oregon (Starkey Experimental Forest and Range). Results are applicable to the Blue Mountains of Oregon and Washington.

The study showed that forested range is improved by deferred rotation. There was little change, however, on intermingled grassland openings. As more cattle were put into the ranges, big game used the areas less. *Carex geyeri,* the most valuable forage plant, was favored by light deferred rotation.

IN THE PACIFIC NORTHWEST

TECHNICAL BULLETIN NO 1531

U.S. DEPARTMENT
OF AGRICULTURE
FOREST SERVICE

The Effect of Cattle and Big Game Grazing on a Ponderosa Pine Plantation, by Paul J. Edgerton (30)

Mixed conifer stands that have been clearcut, planted with trees, and seeded to grass are a potential source of summer forage for livestock and wildlife. The height of trees that had been planted in portions of a clearcut that had been ungrazed, grazed only by deer and elk, and by deer, elk, and cattle were compared. After five growing seasons, grazing had neither greatly harmed nor benefited growth and survival of the trees in the plantation.

A portion of the clearcut grazed by deer, elk, and cattle.

A portion of the clearcut grazed only by deer and elk. Note the abundance of ungrazed timothy. (This area adjoins the area shown at left.)

Art and his boss, Don Schmiege, who head research at the Forestry Sciences Laboratory in Juneau, are particularily concerned about the effect of logging on fish habitat. It is impossible, they say, to know what effect logging at Kadashan had on the fisheries resources there. The fishing is good now. But no one knows how the fishing was before the timber was cut.

''We know logging can be disruptive,'' Schmiege says. ''Certain practices are detrimental to spawning areas and to the habitat of young fish. What we need to do is define their needs at the crucial time of spawning and rearing so foresters and others can make better decisions about how to harvest timber and manage other forest resources.''

Forest managers, too, are concerned about the effect of logging on the fisheries resource. Art's study area is part of the Tongass National Forest, and his work is conducted in cooperation with Region 10, the land management unit of the Forest Service in Alaska. Altogether, the national forests cover 21 million acres, with 16 million acres in the Tongass National Forest. Although the Research branch of the Forest Service and the National Forest System are administered separately, they work hand in hand. And their objectives are the same—to improve forestry practices in Alaska and elsewhere. Information gained from the research will be incorporated into management prescriptions and directives for national forest and other land managers.

''Logging doesn't have to be detrimental to the fishery resource,'' Art says. ''It's a matter of how it's done.''

How covers a lot of territory especially in Alaska where there has been plenty of room to err in the past. Years ago, hardly anyone but foresters and loggers ever saw logged-over areas. But that's changed now. More of Alaska is becoming visible every day.

Art has worked in cooperation with the Alaska Department of Fish and Game on a study to test the effectiveness of minnow traps (wire baskets) to measure the local fish population. In the course of this work, he made many observations about the fish and their habitat requirements. He has also concentrated on studying smaller sections of streams to identify the types of habitat each fish species prefers at different stages of development. He's looking at factors such as streamside vegetation, water velocity,

Response of Understory Vegetation to Ponderosa Pine Thinning in Eastern Washington, by Burt R. McConnell and Justin G. Smith (31)

Pine thinnning caused highly significant increases in understory vegetation. After eight growing seasons, total understory yield increments ranged from 75 lb/acre on the unthinned plots to 417 lb under 26-foot pine spacing. The increase comprised 51 percent grasses, 37 percent forbs, and 12 percent shrubs. When pine canopy exceeded about 45 percent, forbs produced more than grasses; below 45 percent, grasses were superior producers. Shrubs were the least productive at all levels.

Logging on Forest Range

First-year effects are reported from a study of logging on Pacific Northwest ponderosa pine ranges. It was found that tractor logging disturbed herbaceous and shrubby vegetation on an average of 21 percent of the ground, and covered 5 percent more with slash. Included within these data was a category of deep soil disturbance to 15 percent of the area. This denudation had a potential of long-term significance of forage and watershed values. Logging with a cable from a jammer was less damaging, and horse logging resulted in the least disturbance.

See a 1951 report, *First-Year Effects of Logging on Ponderosa Pine Forest Range Lands of Oregon and Washington,* by George A. Garrison and Robert S. Rummel (32).

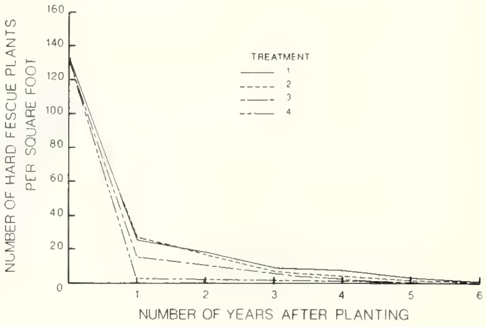
Subsequent publications displayed the slow vegetation recovery that followed the first year assessment of disturbance. Results also pointed out the need for improved logging methods and that reseeding denuded areas will hasten restoration of ground cover and forage. See two items by G.A. Garrison: *Recovery of Ponderosa Pine Range in Eastern Oregon and Eastern Washington by Seventh Year After Logging* (33), and *Changing Conditions in Northwest Forests and Their Relation to Range Use* (34).

George Garrison

Effect of Ponderosa Pine Needle Litter on Grass Seedling Survival, by Burt R. McConnell and Justin G. Smith (35)

Needle litter under stands of ponderosa pine can have an effect on the understory of shrubs and herbaceous vegetation. This may in turn have an effect on use of the areas by cattle.

In the study, researchers found that needle litter had a significant effect on initial survival of fescue seedlings. Subsequent losses probably resulted from several factors.



Number of living hard fescue plants per square foot from seed planting through the 6-year period under four levels of ponderosa pine needle accumulation.

Economics of Forest Range

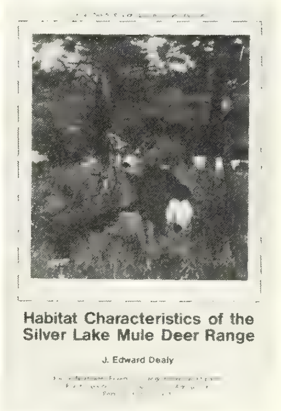
This paper deals with economic returns from planting forage in a shelterwood management regime, with stocking densities typical of those in ponderosa pine-grass areas of eastern Washington. See *Economic Returns from Planting Forage in National Forests,* by Robert W. Sassaman (36).

Idaho Fescue Preference, by J. Edward Dealy (37)

The author discusses the untalked about problem of cattle grazing on Idaho fescue under ponderosa pine—and offers some valuable ideas for ranchers and land managers. Each problem, Dealy indicates, will likely require its own solution. But there are several possible approaches: 1) flash burning grass litter, 2) a year of heavy early grazing to force litter use, and 3) a rotation of forced use and moderate use, being careful not to let pine needles and litter get back on top with too long a wait between "forced use" years.

wildlife habitat

big game



Habitat Characteristics of the Silver Lake Mule Deer Range

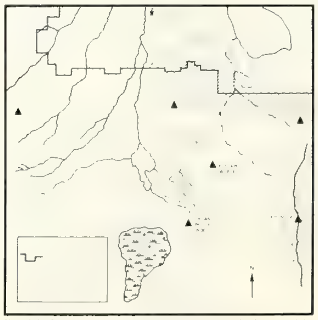
J. Edward Dealy

Habitat Characteristics of the Silver Lake Mule Deer Range, by J. Edward Dealy (38)

Mule deer in central Oregon are migratory. They roam a vast mountainous summer range and crowd into a relatively small winter range. Most of the deer ranges in central Oregon are grazed by livestock, either cattle or sheep or both together. Excessive populations of animals compete for food. Prolonged competition can produce changes in diet, nutrition, fecundity, and range conditions. To prevent or reduce this competition, a wide variety of facts must be gathered concerning the animals and their environment.

This paper presents an analysis of 21 habitats present on the Silver Lake deer range in northern Lake County, Oregon. Treatment includes analysis of site, vegetation, and soils on both the summer and transition (summer-winter range boundary) ranges and discussion of vegetation types for suitability as mule deer habitat. This descriptive work is one of the first steps in developing realistic management plans for maximum sustained and compatible mule deer-livestock production.

Information presented here is directly applicable to the Silver Lake deer herd range. Data can be used as guides for management of deer herd ranges in central and south central Oregon and elsewhere in the western United States under similar conditions.



Map of the Silver Lake area of Oregon showing main topographic features and the division of summer, winter, and spring-fall ranges for mule deer

Forage Use by Deer and Elk

A knowledge of the food and cover preferences of wildlife is necessary in order to effectively manage the animals and their habitat. This is particularly important to managers of public lands who need to balance wildlife use with other important resources.

This paper presents results of a 3-year study of seasonal forage use by deer and elk on part of the Starkey Experimental Forest and Range in the Blue Mountains of eastern Oregon. Three major habitats were sampled: open forest, dense forest, and grassland. Open forest land rated highest as a food and shelter in spring, summer, and fall. This habitat had a season-long abundance of forage, particularly elk sedge, a highly preferred grasslike plant. Grassland rated second in the spring when succulent forbs were abundant but dropped to third during the summer and fall when grassland plants were dry and not very palatable. Deer and elk then sought food as well as cover in the forest.

Details may be found in, *Seasonal Forage Use by Deer and Elk on the Starkey Experimental Forest and Range, Oregon,* by Paul J. Edgerton and Justin G. Smith (39).

Open forest

Dense forest

Grassland

Big Game Use and Habitat Changes in a Recently Logged Mixed Conifer Forest in Northeastern Oregon, by Paul J. Edgerton (40)

Logging is dramatically changing the character of big game summer ranges in the mixed conifer forests of northeastern Oregon and southeastern Washington. Animal use and habitat changes were documented in recently logged clearcuts, adjoining uncut and nearby partial-cut forest stands. Elk use was highest in the clearcuts, lowest in the partial-cut areas. Deer showed essentially the same order of preference, but differences between habitats were much smaller. Forage was the obvious attraction in the clearcuts. Adjoining uncut stands provided excellent cover. The partial-cut stands lacked both the volume and variety of forage in the clearcuts and hiding cover found in the uncut areas.

The Old 1-2-3, by Burt R. McConnell, Jerry A. Davis, and Paul D. Dalke (41)

Deer management is largely a matter of taking a sufficient harvest to protect food supplies during the winter months. Reduction for the winter stress period is what game managers are usually after when they recommend heavier hunting on certain herds. They know that in a healthy herd spring fawning will restore numbers to a high level. Normally, under this kind of management, losses are low, reproductive rates are high, and hunters are using the full annual increment of the herd.

This is what managers had in mind for the Cassia deer herd after a cooperative interagency study group took stock of things in the early 1940's. This herd ranges in part of the Sawtooth National Forest, and adjacent Bureau of Land Management lands, southeast of Twin Falls. Over the years it has been one of Idaho's top-ranked mule deer producers.

During the early 1940's, extensive deer population studies and range surveys were conducted which indicated a winter range carrying capacity of about 10,000 deer and a population of 13,000-14,000 deer. These studies also showed that too many livestock were using the area, so plans were drawn up for a coordinated program aimed at reducing both deer and livestock to proper stocking levels. Sheep allotments were generally in poorer condition than cattle allotments, so they were targeted for the heaviest reductions. When this overall program was initiated in 1943, no one figured it would take nearly 20 years to complete.

The authors discuss this program, and outline a basic 1-2-3 approach to deer and livestock management:

1) balance deer and livestock with carrying capacity,
2) as a result, forage conditions improve, and
3) fawn production increases on Idaho's Cassia Division deer range.

volume, water depth and width of the stream, natural cover, bottom type, and the type of food available for the young fish.

Art hopes to develop enough information to write management prescriptions for protecting fish habitat during and after logging.

From his studies, Art believes that almost all streams, regardless of how small they are, provide rearing habitat for fish. This means more attention should be paid to protecting very small streams during logging. ''Coho may not spawn in these streams, but they are vitally important for rearing the young fish,'' he says.

Currently, good management practice calls for foresters to carefully evaluate the natural vegetation along major streams in order to insure productive salmon spawning habitat. But small streams, which have rearing or resident populations may or may not support spawning populations, were ignored up until a few years ago. And there has been little or no research on the role of these smaller streams—the type Art is studying now. Most studies have been conducted on habitat for pink and chum salmon, the most valuable of the commercial fish in Alaska. These two species have a short freshwater life and spend most of their life cycle in the open sea. But other species are becoming more valuable. These include coho, king, and sockeye salmon, rainbow and cutthroat trout, and Dolly Varden. All these species have a freshwater rearing stage and some have populations that remain in fresh water throughout most of their life cycle. Dolly Varden and trout are most typical of these.

In the main Kadashan River and the larger tributaries, coho may go 10 to 12 miles upstream to spawn. Pinks and chums go almost that far, but concentrate more in the lower reaches. After the young coho hatch, they move into backwaters and eddies, or into smaller tributaries.

These are some of the most productive fisheries waters in the world. But they will stay that way only if the vital habitat of the fish is protected. The potential conflicts between logging or other land use activities and fisheries are obvious. But experts such as Art Bloom believe we can have both. The answer certinly lies in a more thorough understanding of the needs of the fish throughout their life cycle.

end

next "insight" page 145

Yukky to Yummy—With Fertilizers, by J. Michael Geist, Paul J. Edgerton, and Gerald S. Strickler (42)

Webster's unabridged does not define "yukky," but we think it means not tasty. In this study, the authors describe how fertilization of timothy grasses on summer ranges in eastern Oregon helped make them more attractive to wildlife, especially elk.

Researchers suggest a unique use of this information. For example, people enjoy viewing wild animals; fertilizers might be used to attract elk to locations where they could be seen readily.

Timothy grass

Forage Quality as a Tool in Wildlife Management, by W.O. Hanson and Justin G. Smith (43)

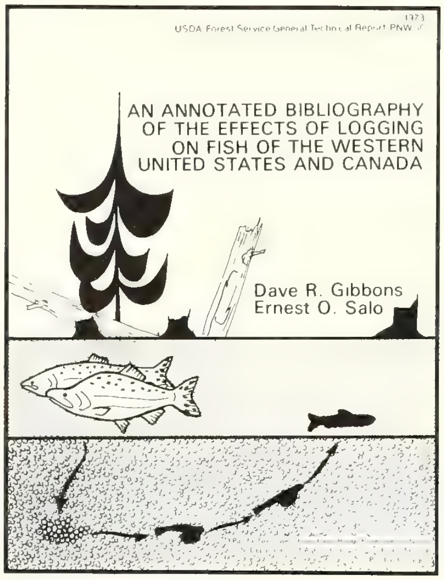
This is not a research paper, but a thoughtful discussion of forage quality as a tool in wildlife management. Three major topics are discussed: 1) the effect of forage quality on animal production, 2) improvement of forage quality through management practices, and 3) research needs. Management techniques considered include: timber cutting, mechanical treatment of brushland, herbicide treatment, prescribed burning, fertilizing, and plantings as attractants to wildlife.

Immobilization of Rocky Mountain Elk Using Powdered Succinycholine Chloride, by Richard J. Pedersen and Jack Ward Thomas (44)

If you want to immobilize an elk for any reason, you may want to read more about this study. Researchers used darts filled with a neuromuscular blocking agent called succinylcholine chloride to quiet the animals after they had been trapped. On the average, it took a dose of about 26 mg to do the job, an average of about 7 minutes to achieve the immobile state, a condition which lasted an average of 24.5 minutes. Timing is important! Some animals recover quicker than others.

For another publication in this category, see item in the bibliography under (45).

other



1973
USDA Forest Service General Technical Report PNW-

AN ANNOTATED BIBLIOGRAPHY
OF THE EFFECTS OF LOGGING
ON FISH OF THE WESTERN
UNITED STATES AND CANADA

Dave R. Gibbons
Ernest O. Salo

An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada, by Dave R. Gibbons and Ernest O. Salo (46)

This bibliography is an annotation of the scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the Western United States and Canada. It includes 278 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids, multiple logging effects, alteration of streamflow, stream protection, multiple-use management, streamside vegetation, stream improvement, and descriptions of studies on effects of logging. A review of the literature, a narrative on the state of the art, and a list of research needs determined by questionnaires are included.

Equal Time for Non-Game Species, by Jack Ward Thomas (48)

There is an old saying, "Variety is the spice of life." Variety (diversity) is also the spice that provides the requirements of myriad wildlife and a fail-safe principle for comprehensive land use planning.

Thomas discusses various principles of wildlife management and how they relate to land use planning. First, he says, most wildlife biologists are trained to know the most about game animals and pest species. But most wildlife fit neither of these categories. Planning suitable habitats for each of those species would be an impossible task. But when planning is done to ensure that important "habitats" are not destroyed, then the individual wildlife species will be assured their important ecological niche.

Further, he says, a valuable habitat for wildlife is one that is also desirable for people. Consider some urban environments where sparrows, starlings, pigeons, and rats are the only kind of wildlife. Compare this with an environment that has catbirds, robins, orioles, and squirrels. In the first place, there is little diversity; buildings are crowded and vegetation is sparse. In the second, there are trees, shrubs, and grass in diversity.

Germination of Cascara Seed, by M.A. Radwan (49)

Cascara seeds are dormant when the fruit is mature and the seed is dispersed. This dormancy can be broken by artificial stratification for 4 months or by soaking in potassium gibberellate prior to spring sowing. Cascara trees provide protection for watersheds and food and cover for wildlife.

Silvicultural Options and Habitat Values in Coniferous Forests, by Thomas, Crouch, Bumstead, and Bryant (47)

The coniferous forest moves through successional stages from bare ground to old-growth stands. Each stage in succession is more or less favorable to each bird group in terms of habitat requirements, and therefore, there is a successional pattern in the avifauna reflecting changes in the forest vegetation.

Silvicultural treatments have the general effect of modifying successional patterns to achieve some timber-related objective to speed up succession, to select for certain plant species, to concentrate growth on selected stems, or to harvest valuable commodities. The effects of such silvicultural options are predictable and controllable.

Birds are a natural part of the coniferous forest biome. They evolve with it and influence the system as well as being influenced by it. The effects of birds in the population dynamics of forest insects is one role that we have discussed.

Applied fire management is just coming into its own. Fire can be used for several purposes—but primarily results in alteration of ground cover or successional patterns.

Opportunities for wildlife biologists to attain their forest management goals were never better. Many, if not most foresters are now receptive to reasonable proposals to enhance bird habitats or at least to minimize adverse impacts of silvicultural practices on the habitats. However, biologists must provide factual, professional, and realistic leadership in planning and implementing land management policies and programs if habitat diversity is to be maintained.

range and wildlife – bibliography

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recreation

See also:
Silviculture
Insect and Disease
Range and Wildlife
Gadgets

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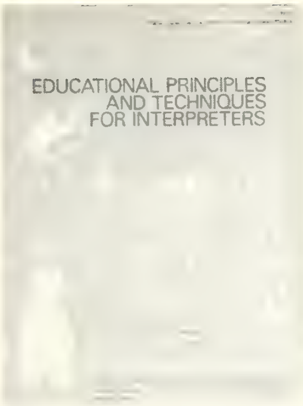
interpreting the environment



EDUCATIONAL PRINCIPLES AND TECHNIQUES FOR INTERPRETERS

Educational Principles and Techniques for Interpreters, by F. David Boulanger and John P. Smith (1)

To make the insights of educators available to interpreters, principles and techniques for effective talks and discussions have been summarized. Coverage includes objectives, selecting and organizing visitor experiences, motivation and attention-holding techniques, use of questions, and use of examples, analogies, and metaphors. A checklist is included along with a bibliography for readers wanting additional information.

Evaluating Visitor Response to Exhibit Content, by Randel F. Washburne and J. Alan Wagar (2)

The effectiveness of various exhibit characteristics was studied in four visitor centers: two in Mount Rainier National Park, one in Olympic National Park, and one in the Siuslaw National Forest in Oregon.

Results indicate a preference for dynamic presentations such as movies, audio sequences, and exhibits with changing lighting. People also preferred three-dimensional presentations, themes of violence and destruction, mammals and birds, ecological relationships, and holistic presentations of cause and effect relationships or parts making a story.

Because visitors tended to prefer the more expensive exhibits, future studies should consider not only effectiveness but cost-effectiveness.

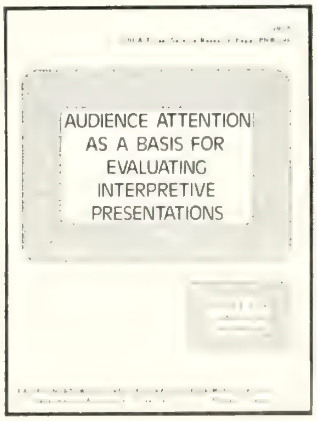
Visitor Groups and Interpretation in Parks and Other Outdoor Leisure Settings, by Donald R. Field and J. Alan Wagar (3)

To inform visitors and enhance their experiences, resource managers responsible for interpretation must understand both human behavior and resources. Five principles for effective interpretation are suggested: (a) visitors are diverse, (b) visitors anticipate a relaxed and enjoyable atmosphere, (c) interpretive information must be rewarding, (d) interpretive information must be understood, and (e) the effectiveness of interpretation must continually be evaluated.

This report was published in the *J. Environmental Educ.* 5(1):12-17, and reprinted in *Guideline* 4(2):13-24, 1974. It was also published as "People and Interpretation," Chapter 3 (p. 43-56) in *Interpreting the Environment,* Grant W. Sharpe (ed.). 1976. John Wiley & Sons. New York. 556 p.

Objectives and Evaluation in Interpretive Planning, by Allen D. Putney and J. Alan Wagar (4)

Effectiveness cannot be evaluated unless objectives have been specified in terms suited to measurement. To gain the advantages of broad planning goals as well as specific and measurable behavioral objectives, a hierarchy having three or more levels of objectives is suggested. Each broad policy goal at the top is supported by more specific objectives that are consistent with that goal. Each of these objectives is in turn supported by even more specific objectives that are consistent with the objective and goal above it. Measured achievement of the most specific objectives then permits us to infer that the policy goals are also being achieved.



AUDIENCE ATTENTION AS A BASIS FOR EVALUATING INTERPRETIVE PRESENTATIONS

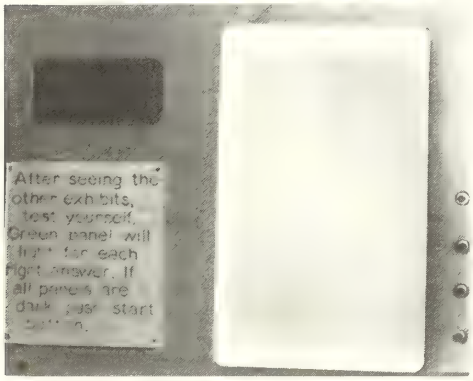
Audience Attention as a Basis for Evaluating Interpretive Presentations, by Ronald E. Dick, Erik Myklestad, and J. Alan Wagar (5)

How can interpreters find out how visitors respond to presentations without having to ask questions? This paper presents a tested technique for recording audience attention at 1- or 2-minute intervals. Where possible, observers watched people's eyes. If that was not practical, watching the orientation of people's heads was a good method. Graphed records of audience attention showed substantial differences both within and between presentations.

The Recording Quizboard: A Device for Evaluating Interpretive Services, by J. Alan Wagar (6)

Describes a device to help interpreters evaluate the effectiveness of presentations. After a visitor has passed through an exhibit, he comes to a sign which says: "Test yourself. Green panel will light for each right answer. If all panels are dark, push start button."

The answers on the panel—both right and wrong—are recorded and tell the interpreter which exhibits are most effective in producing right answers. The interpreter can then change the exhibit and check again to see if people are getting the message.



A Summary and Annotated Bibliography of Communications Principles, by Ronald E. Dick, David T. McKee, and J. Alan Wagar (7)

Principles from communications and related fields are directly pertinent to environmental education and interpretation. However, the people who usually design, present, and administer these programs often lack formal training in communications. As a result, valuable information often has not been readily available to them.

This summary and annotated bibliography have been assembled specifically to provide environmental educators and interpreters with the major principles from communications and related fields. Principles are summarized under headings of Communicator or Source Factors; Communication or Message Factors; and Receiver or Audience Factors.

Interpretation to Increase Benefits for Recreationists, by J. Alan Wagar (8)

To be effective, interpretation must attract and hold attention. For greatest interest, interpretation must be dynamic, rewarding to visitors, easily obtained, tailored to diverse visitors, and meaningfully structured. Evaluation of effectiveness requires feedback from visitors and objectives for which achievement can be measured.

Challenging the Folklore of Environmental Education, by John C. Hendee (9)

Environmental education and related programs now attract more attention than ever before. In many cases, the recent attention and importance of environmental education has led to the approval and financing of long awaited proposals. Environmental educators should rejoice at the new importance and recognition of their field and attempt to capitalize on their current popularity. But at the same time, a critical eye should be directed at the traditional approaches that are likely to capture and direct the increased appropriations for environmental programs.

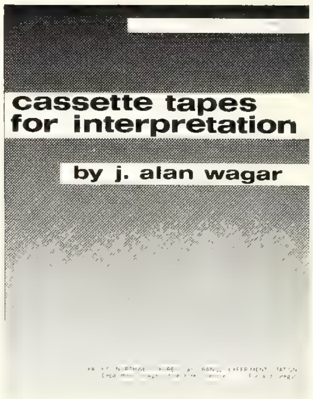
The increased importance of environmental education is well founded. But are the capabilities, accumulated knowledge, and conventional tools of environmental education up to the challenge? Will the imminent investments in environmental education efficiently contribute to the alleviation of environmental problems? Is the growing complexity of environmental problems matched by growth in the sophistication of method, technique, and objectives among environmental educators? These are reasonable questions and might be constructively used in a critical self appraisal by professionals in the field. From my perspective the view is not encouraging. Recent experience and a review of literature and research in the field of environmental education and related topics left me with some unfavorable impressions and triggered some suggestions for improvement.

Research in Interpretation, by J. Alan Wagar (10)

Three kinds of studies useful for increasing the effectiveness with which natural and cultural resources are interpreted are discussed: (a) studies providing interpreters with summaries of knowledge from such disciplines as psychology, sociology, communications, and education; (b) studies to evaluate costs and effectiveness of alternative interpretive procedures; and (c) studies to develop feedback methods that interpreters can use to evaluate audience response to presentations.

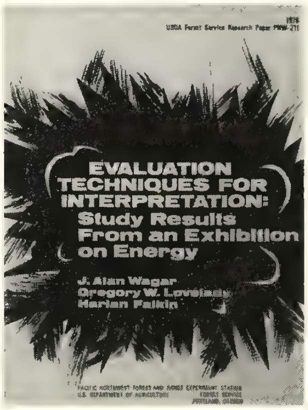
Evaluating the Effectiveness of Interpretation, by J. Alan Wagar (11)

The changes in attitudes or behavior brough about by interpretation are extremely difficult to measure. However, so much interpretation fails on the prosaic matters o gaining attention and understanding tha their measurement is useful for evaluating effectiveness. The advantage and disadvantages of 12 evaluation techniques are discussed.



Cassette Tapes for Interpretation, by J. Alan Wagar (12)

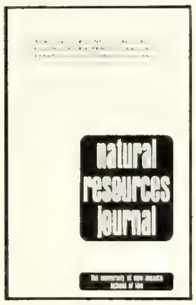
Interpretation using portable tape players and cassettes provided greater enjoyment and retention of information on a visitor trail than either trail signs or a trail leaflet. Questions within a tape increased visitor retention of information so emphasized but at the risk of reduced retention for other information. On-the-ground costs were estimated as between 4 and 9 cents per visitor contact.


1976
USDA Forest Service Research Paper PNW-211
EVALUATION TECHNIQUES FOR INTERPRETATION:
Study Results From an Exhibition on Energy
J. Alan Wagar
Gregory W. Lovelady
Harlan Falkin
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PORTLAND, OREGON

Evaluation Techniques for Interpretation: Study Results From an Exhibition on Energy, by J. Alan Wagar, Gregory W. Lovelady, and Harlan Falkin (13)

Six techniques for evaluating presentations were studied during an exhibition on man and energy at the Pacific Science Center, Seattle, Washington. A panel of outsiders, suggestion boxes, observed audience attention, and time-lapse photography all proved to be good for evaluating effectiveness.

public involvement



Analyzing Public Input

A system is described that enables forest resource managers to analyze input from public involvement processes. The system is Codinvolve, a method which uses edge-punch card sorting techniques to summarize people's comments on resource management issues. A computer may also be used.

The common denominator of all public input is defined and six broad principles listed. In addition, Codinvolve meets a number of other important criteria. It accurately summarizes the content of public involvement in relation to the decisionmakers' questions. And it can provide other descriptive and qualitative information about the input. It is objective, reliable, has a certain flexibility, and can be uniformly applied among different administrative units. It can handle, store, and retrieve large quantities of input. And the procedures used are visible and traceable so that interested people can review the public involvement process.

The report is *Analyzing Public Input to Resource Decisions: Criteria, Principles and Case Examples of the Codinvolve System,* by Roger N. Clark and George H. Stankey (14).

A companion report which discusses the Codinvolve system in more detail is *An Introduction to Codinvolve: A System for Analyzing, Storing, and Retrieving Public Input to Resource Decisions,* by Roger N. Clark, George H. Stankey, and John C. Hendee (15).

Foresters' Views of Interest Group Positions on Forest Policy, by Gordon L. Bultena and John C. Hendee (16)

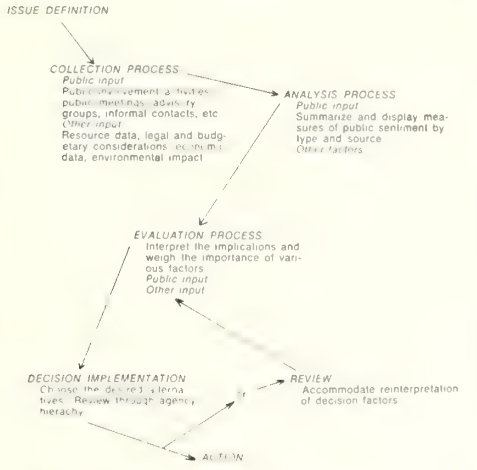
Foresters on five national forests in the Pacific Northwest, when identifying special interest group positions on timber cutting, aligned themselves with commercial vs. recreational-aesthetic interests, viewing the latter as having unjustified expectations. On the issue of opening trails to motor bikes foresters saw a split among recreational interests.

A Framework for Agency Use of Public Input in Resource Decision-Making, by John C. Hendee, Roger N. Clark, and George H. Stankey (17)

A thoughtful discussion of public involvement as an aid to help resource managers in the decision making process. In summary, the authors conclude that failure to solicit public participation aggressively and innovatively—and respond to it—can result in the loss of agency stature, damaging public criticism of agency policies and programs, and continued antagonistic situations between the agency and some of its clientele. Public participation is unlikely to eliminate confrontations with polarized constituents, but it can bring out and focus the conflict well in advance of the deadline for making a decision.

Pressures to secure better public input are, in part, a response to the public's demands for a greater voice in land management. By increasing public participation in decision-making, public agencies should avert disastrous mistakes and diminish *ex post facto* confrontations.

But the issue is a broader one. Public involvement provides a forum in which the public can effectively exert its rightful role as a goal-setting body. On the other hand, with a more accurate assessment of public desires, professional managers can better fulfill their role as achievers of those goals.


ISSUE DEFINITION
COLLECTION PROCESS
Public input
Public involvement activities public meetings advisory groups, informal contacts, etc
Other input
Resource data, legal and budgetary considerations economic data, environmental impact
ANALYSIS PROCESS
Public input
Summarize and display measures of public sentiment by type and source
Other factors
EVALUATION PROCESS
Interpret the implications and weigh the importance of various factors
Public input
Other input
DECISION IMPLEMENTATION
Choose the desired alternatives. Review through agency hierachy
REVIEW
Accommodate reinterpretation of decision factors
ACTION

Processes for using public input in resource decision making.

Public Participation in Forest Management Decisions, by J. Alan Wagar and William S. Folkman (18)

Diverse interest groups, often with conflicting goals, are demanding voices in setting land management goals. If they are to reflect informed opinion, compromise and opportunities for mutual advantage, managers and conflicting interest groups must interact sufficiently to identify trade-offs. Small working groups, with sustained interaction among representatives of conflicting interests, offer a solution.

PHEROMONES FOR INSECT CONTROL

by Dorothy Bergstrom

The search continues for better ways to cope with future Douglas-fir tussock moth outbreaks. One of the most promising new control techniques may be the pheromone, or sex attractant, of the tussock moth, produced artifically in the laboratory in 1974. Development of the artificial sex attractant, which duplicates the natural attractant of the moth, may soon make it possible to determine the location and size of local populations. Eventually the attractant may also be developed as a control technique.

The scientific team that identified and synthesized the pheromone is headed by Dr. Gary Daterman, an entomologist at PNW Station's Forestry Sciences Laboratory in Corvallis; and Dr. Doyle Daves and Dr. Ronald Smith, chemists at the Oregon Graduate Center, Beaverton, Oregon. Supporting and assisting them are technicians who perform highly specialized tasks. Dr. Lonne Sower, a recent transfer from the Agricultural Research Service, is an experienced pheromone scientist who has joined this team to assist in development of pheromones of tussock moths and other insects.

In 1973, the same team identified the sex attractant of the pine shoot moth. Using similar laboratory and field procedures, they are now working to identify the attractants of the western tussock moth and the rusty tussock moth. Though these insects are far less destructive to Northwest conifers, scientists are interested in their attractants because these moths are closely related to the Douglas-fir tussock moth. In the woods they may even be attracted by the same pheromone.

In their collaboration, which began in 1970, Daterman, Daves, and Smith have developed their own investigative methods for tuning in on insect communication. It is a process, that requires perseverance and, most of all, cooperation between the chemist and the entomologist.

The first step is to find out whether the insect has an attractant and, if so, which sex produces it. To start with, the entomologist grinds up the abdomens of female insects

camping

Guidelines for Roadless Area Campsite Spacing to Minimize Impact of Human-Related Noises, by T. Dailey and D. Redman (19)

Guidelines for campsite spacing and location in roadless areas are presented which allow insulation from noise between campsites. The guidelines are based on the distance that different human-related noises travel in a variety of outdoor settings. Eleven human-related noises were measured, four of which were: trail bike motor, conversation, gunshot, and chopping wood.

The physical and psychological properties of these noises are described and discussed. The effects of different environmental features—ridges, hills, dense woods, low vegetation, still water—on noise transmission are also described. General management actions are suggested for locating camps to minimize noise from other camping parties.

Recreational Carrying Capacity Reconsidered, by J. Alan Wagar (20)

In designing guidelines for protecting recreational resources, managers have long borrowed the concept of carrying capacity from the fields of range and wildlife management. In many ways, it was a bad choice that has diverted our attention from more promising approaches to effective management of recreation lands.

Because recreation areas produce psychological experiences, acceptable levels of use depend greatly on desired qualities of experience, management patterns, and such off-site factors as alternative opportunities and visitor characteristics.

The "Adequacy" of World Recreation Resources, by J. Alan Wagar (21)

Vast differences in the wealth, value systems, technology, and other characteristics of different nations make American standards inappropriate for defining ''adequate'' recreation resources on a worldwide basis. Worldwide, people's expectations for recreation will generally be shaped by supply rather than *vice versa.*

wilderness

Wilderness Users in the Pacific Northwest—Their Characteristics, Values, and Management Preferences, by J.C. Hendee, et al (22)

Wilderness users were canvassed during the summer of 1965 in the Glacier Peak Wilderness in Washington and the Eagle Cap Wilderness and the Three Sisters Wilderness in Oregon. These areas were chosen because they were the three most heavily used wilderness areas in the Pacific Northwest. Each was dominated in use by a different type of visitor: backpackers in Glacier Peak, horseback riders in Eagle Cap, and 1-day hikers in the Three Sisters.

The authors sought to determine what kinds of persons visit wilderness in the Northwest, what values and codes of behavior they associate with wilderness use, and how they feel about certain policies that might be used in the management of such areas. The study is based on the response of 1,350 persons to an eight-page questionnaire that was sent to a random sample of visitors recorded during 1965.

[illegible] ak Wilderness is particularly [illegible]

Motivations of Wilderness Users, by W.R. Catton, Jr. (23)

Wilderness user motivations can be deduced from study of users' characteristics and behavior. Motivations for wilderness use are learned, and increasing numbers of people will learn them from each other, from contact with wilderness environments, and from conservation organizations and resource management agencies.

Motivation toward a wilderness goal, such as mountain climbing, tends to be highest if the goal outcome is uncertain. If it is a certainty that the summit will be reached, or that it is impossible, then motivation is less. Motivation toward a less demanding goal, such as hiking and camping, may be governed more by the mystery that the endeavor holds for the user.

Camping may be motivated greatly by the desire to participate in a way of life that is thought to be free from crime such as theft. Even when users have some valuable items stolen, they tend to be reluctant to redefine the campground as anything but a crime-free environment. This attitude may be indicative of a major motivation for camping —the desire to live in a morally and socially dependable world for a time.

Apparently, another motivation for camping is the desire to escape the usual necessity for considering the consequences of one's actions. Also, the social side of camping may be an important part of the camper's motivation.

Wilderness use results from positive attractions by the natural environment as well as from mere repulsion by urban environments. Campers seek opportunities for social contact with chosen companions, but are also motivated by a quest for privacy which can be gained either from geographic remoteness in back country areas or from adherence to a norm of non-involvement in intensively used campgrounds. Educated, professional, urban-bred users of wilderness tend to prefer the natural environment and be advocates of preservation and wilderness. These attitudes may be expected to become even more prevalent.

A Scientist's Views on Some Current Wilderness Management Issues, by J.C. Hendee (24)

The author expresses opinions on issues concerning the professional's role in allocation and management of wilderness, the need for a comprehensive public-land policy to preserve that wilderness, the need for a pure approach to wilderness management, mandatory wilderness permits, and rationing wilderness use.

Resource professionals play a vital role in developing strategies for managing wilderness in ways that assure its preservation.

Wilderness is vulnerable to impacts which occur outside its borders. Comprehensive land management is critical to protect it from erosion.

Two opposing philosophies compete for the allegiance of wilderness managers. The anthropocentric approach centers on enhancing man's use of the natural environment. By contrast the biocentric (or "pure") approach emphasizes the natural integrity of wilderness ecosystems because the values of wilderness ultimately depend on the natural processes of environmental change operating independent of man's interference. The author endorses the biocentric or pure approach on both philosophical and practical grounds.

Mandatory Wilderness Permits: A Necessary Management Tool, by J.C. Hendee and R.C. Lucas (25)

A mandatory wilderness permit system is suggested for providing essential management information on use, provide a means of influencing visitor behavior, and control overuse when necessary.

The authors explore some costs and benefits of mandatory permits, basing their judgement on relevant research findings, experience with wilderness registration and permit systems, and on an assessment of the need for such control.

Wilderness permits offer valuable information to help resource managers preserve the integrity of wilderness experience without resorting to rationing use. This should be the last alternative to which we turn after exhausting all other means to control the impact of use. A major challenge to resource managers and researchers is the development of wilderness management techniques capable of controlling or redistributing the impact of use within acceptable limits.

Biocentricity in Wilderness Management, by J.C. Hendee and G.H. Stankey (26)

Two contrasting philosophies on wilderness management are identified and evaluated: anthropocentric versus biocentric. The "anthropocentric" philosophy emphasizes man's use of wilderness as the primary objective, while the "biocentric" philosophy emphasizes the importance of maintaining the natural integrity of wilderness ecosystems at the expense of recreational and other human use, if necessary. The authors endorse the biocentric view, summarize arguments for and against this philosophy, and call for further debate on these issues in scientific, professional, and political circles.

vandalism and littering

Values, Behavior, and Conflict in Modern Camping Culture, by Roger N. Clark, John C. Hendee, and Frederick L. Campbell (27)

Research findings suggest that campers and managers subscribe to similar goals associated with camping, but they disagree about the types of activities appropriate to attaining those goals. In addition, there seem to be important differences in the way both groups perceive behavioral problems in campgrounds. Campers express less concern than managers about problems such as vandalism, theft, and nuisance behaviors. These differences are thought to be attributed to the social goals and urban behavior patterns of campers compared to the more traditional, natural environment-oriented expectations for camping behavior held by recreation managers. Certain changes in recreation user populations and in the organization of public campgrounds are discussed in relation to behavior problems. A strategy is recommended to avert problems inherent in continued change in the camping scene.

Roger Clark

and mixes them in a solution. This is filtered and tested on male moths in cages. If the males respond, the solution contains an attractant. In addition to the mysterious attractant, it also contains hundreds of miscellaneous compounds that are unrelated to the pheromone. Before the pheromone can be identified, it must be isolated from these other chemicals.

The purification process is a sort of laboratory do-si-do in which the entomological and chemical teams take turns performing their specialized procedures. The chemist's job is to eliminate all compounds except the pheremone. The entomologist's job is to test the material on male moths to verify attractiveness of test samples.

The chemists use column and gas chromatography and mass spectrometry to seperate the various compounds and divide the solution into small fractions. The entomologist tests each fraction on male moths in a laboratory cage. The fractions which attract moths are separated further and the resulting fractions again tested on male moths. This process may be repeated dozens of times until only the attractive chemical remains.

Finally, the chemists are able to make a substance identical to the one female moths produce effortlessly and unknowingly. The chemical that attracts the Douglas-fir tussock moth is cis-6-heneicosen-11-one. It is highly attractive to male moths regardless of whether it comes from a female moth or a chemical laboratory. A one-nanogram sample—35 trillionths of an ounce—is enough to attract male moths in laboratory tests.

In 1975, field studies to develop new control methods for the Douglas-fir tussock moth were carried out by Forest Service and cooperating researchers under an accelerated

Controlling Vandalism in Recreation Areas—Fact, Fiction, or Folklore?, by Roger N. Clark (28)

Problems with vandalism in private and public recreation areas are increasing. Vandalism results in serious impacts on management budgets, quality of the environment, and recreationists' experiences. The nature of the literature on vandalism is described, solutions discussed, and research needs outlined.

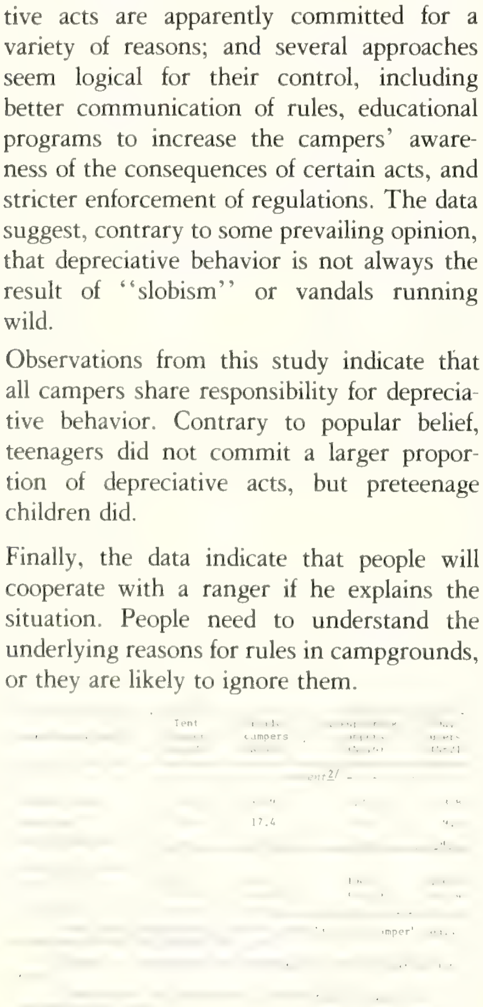
Pacific Northwest Forest and Range Experiment Station
USDA Forest Service Research Note
Forest Service · US Department of Agriculture · Portland, Oregon

Depreciative Behavior in Forest Campgrounds: an Exploratory Study, by Roger N. Clark, John C. Hendee, and Frederick L. Campbell (29)

Vandalism, theft, littering, rule violation, and nuisance behaviors were studied in three campgrounds during 1968. Depreciative acts are apparently committed for a variety of reasons; and several approaches seem logical for their control, including better communication of rules, educational programs to increase the campers' awareness of the consequences of certain acts, and stricter enforcement of regulations. The data suggest, contrary to some prevailing opinion, that depreciative behavior is not always the result of "slobism" or vandals running wild.

Observations from this study indicate that all campers share responsibility for depreciative behavior. Contrary to popular belief, teenagers did not commit a larger proportion of depreciative acts, but preteenage children did.

Finally, the data indicate that people will cooperate with a ranger if he explains the situation. People need to understand the underlying reasons for rules in campgrounds, or they are likely to ignore them.



Types of depreciative acts committed by different types of campers.

How to Control Litter in Recreation Areas: the Incentive System
by Roger N. Clark

How to Control Litter in Recreation Areas: the Incentive System, by Roger N. Clark (30)

The smiling children on the cover of this publication have just helped a Forest Service Ranger clean up a campground, and they're pleased as punch. Not only did they do a good job and receive the praise of the ranger and their parents, they got some tangible rewards to keep—Smokey Bear badges, posters, comic books, and other goodies.

The paper describes the "incentive system" for litter control and shows resource managers how to use it in a few easy steps. The system is easy to use, costs almost nothing, and can be adapted for use in developed campgrounds, in dispersed roaded areas, and in backcountry and wilderness.

A "how to" guide for anyone who wants to deal more effectively with litter in outdoor recreation areas.

The "how to" brochure is based on several years of research and practical field tests. This work is reported in three publications listed in the bibliography (31).

Litterbags: an Evaluation of Their Use, by Roger N. Clark, John C. Hendee, and Randel F. Washburne (32)

A study in Mount Rainier National Park indicates that only a very small proportion of the litterbags handed out end up in park trash cans. Most of the remaining litterbags are carried away from the park without being used. Of the two types of litterbags tested, plastic bags were used more often than paper bags.

dispersed recreation

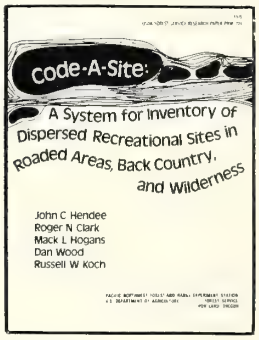
First Results of a Study

Data gathered during the first year of a 3-year study of dispersed recreation along forest roads in Washington and Oregon are described. Dispersed road recreation includes both overnight camping at undeveloped sites and day activities which take place along and adjacent to forest roads.

An inventory indicated that campers had established 622 camp sites along the 333 miles of road in the three study areas. Most of the sites were located near water. Most of the use was on weekends and holidays. In one of the areas, 40 percent of the use was during elk season.

Observations of 1,613 dispersed recreation parties, and conservationists with many of them, indicated that 91 percent had visited the areas previously. Eighty-five percent lived within 100 miles.

The report is *Dispersed Recreation on Three Forest Road Systems in Washington and Oregon: First Year Data,* by John C. Hendee, Mack L. Hogans, and Russell W. Koch (33).


Code-A-Site:
A System for Inventory of Dispersed Recreational Sites in Roaded Areas, Back Country, and Wilderness
John C Hendee
Roger N Clark
Mack L Hogans
Dan Wood
Russell W Koch

Inventorying Sites

Code-A-Site is a system for inventorying dispersed recreation sites on forest roads, in back country, or wilderness. Dispersed sites in these settings have usually been established by impromptu use of recreationists but are important to management since they are the focal point for considerable recreation activity. Code-A-Site uses edge-punch cards for recording and storing basic information about dispersed sites for subsequent retrieval as needed for planning, management, and research purposes. Use of edge-punch cards and needle-sorting methods, facilitates easy summary and analysis of data at field levels. Code-A-Site is designed for field use but provides opportunity for transfer of data to centralized computer storage and retrieval systems if desired.

See *Code-A-Site: A System for Inventory of Dispersed Recreation Sites in Roaded Areas, Back Country, and Wilderness,* by John C. Hendee, et al (34).

wildlife management

A Multiple-Satisfaction Approach to Game Management, by J.C. Hendee (35)

A new multiple-satisfactory approach to game management is proposed wherein the most significant direct products of management are hunting experiences which produce human satisfactions. This approach is different from traditional game-bagged and days-afield concepts which are now viewed as no longer adequate to measure the results of game management.

Six tenets of this multiple-satisfaction approach are outlined and illustrated with suggestions given for their application.

The multiple satisfaction concept of recreation resource management

[illegible]	[illegible]	[illegible]
RESOURCE	OUTDOOR RECREATION RESOURCES	GAME AND FISH
MEANS OF UTILIZATION how the resource is tapped [illegible] a product	RECREATIONAL ACTIVITIES AND EXPERIENCES	HUNTING AND FISHING
PRODUCT what [illegible] from the resource	MULTIPLE SATISFACTIONS	EXERCISE, DISPLAYING SKILL, COMPANIONSHIP, SUCCESS, ETC
GOALS [illegible] of management	HUMAN BENEFITS	PHYSICAL BENEFITS such as health; PSYCHOLOGICAL BENEFITS [illegible]; PERSONAL BENEFITS such as [illegible]; ECONOMIC BENEFITS [illegible]

Hunting Satisfaction: Game, Guns or Nature?, by D.R. Potter, J.C. Hendee, and R.N. Clark (36)

Hunting satisfaction is complex and consists of many elements or aspects of the hunting experience. Different hunters gain varying degrees of satisfaction from the different elements. A questionnaire was sent to hunters and a multiple-satisfaction model developed from the responses. The model indicates that the capacity to provide hunters with the satisfactions they seek may decline before either the amount of game or sheer physical space becomes a limiting factor.

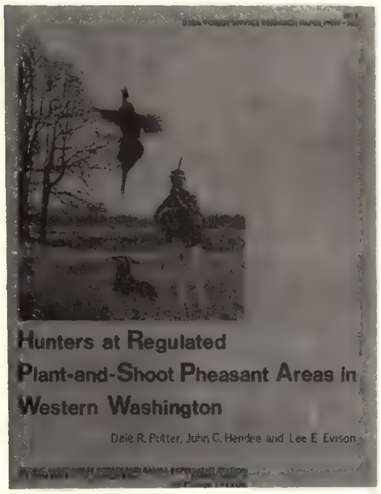
The growth of hunting, coupled with relatively little potential for change in the amount of game and land available, indicates that the numbers of hunters will have to be managed carefully—perhaps limited to maintain opportunities for quality hunting of whatever kind.

Generic and specific satisfactions from hunting.

Generic satisfactions Important to all kinds of hunting, but form and intensity may vary	*Specific Satisfactions* (Importance as well as form and intensity varies with kind of hunting
Nature	Skill
Escapism	Vicariousness
Companionship	Trophy Display
Shooting	Equipment
Harvest	
Outgroup verbal	
Outgroup visual	

Social Science, Social Scientists, and Wildlife Management, by R.N. Clark (37)

Integrating social science perspectives and methods into wildlife programs is urged by the author. He further suggests that long term, continuous interaction between social scientists and wildlife managers, at many levels of expertise, is necessary to facilitate the sharing of knowledge and viewpoints. Specific problems associated with the relationship between social and wildlife sciences are discussed, and recommendations outlined.

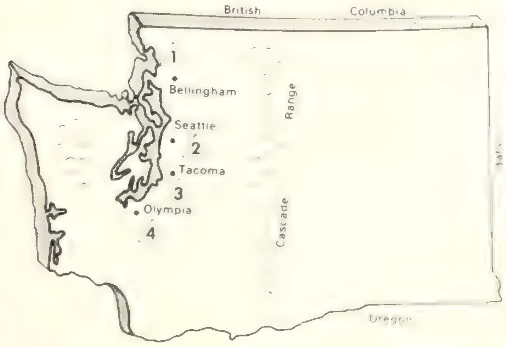


Hunters at Regulated Plant-and-Shoot Pheasant Areas in Western Washington

Dale R. Potter, John C. Hendee and Lee E. Evison

Hunters at Regulated Plant-and-Shoot Pheasant Areas in Western Washington, by D.R. Potter, J.C. Hendee, and L.E. Evison (38)

Hunters visiting four public plant-and-shoot pheasant-hunting areas in Washington's Puget Sound basin were studied by use of a mail questionnaire. Findings suggest positive values from a popular program, the need to reduce crowding, a need to more equitably distribute hunting success, and a revenue potential from a user charge. Hunter's sex, age, education, occupation, income, residence, organization membership, and hunting-related reading habits, motives, complaints, and success are described. Management recommendations are developed from the study findings.



Location of the four regulated plant-and-shoot pheasant hunting areas studied in Washington: (1) Lake Terrell, (2) Stillwater, (3) Fort Lewis, (4) Scatter Creek.

research program of the U.S. Department of Agriculture. Nine western states and British Columbia were involved. All cooperators reported captures of moths in areas where they could not be detected by other methods. In addition to Douglas-fir tussock moth, three other species were attracted by the chemical. Methods have been worked out to distinguish the different species captured in the cages.

With pheromone studies the primary effort is to develop an effective trapping procedure. Researchers tested trap design, trap placement, the number of traps needed in an area, and the attractant dosages needed. The goal is to determine the relationship between the number of moths trapped to the total number in a given area. When applied over a wide area, a trapping system could pinpoint areas where populations are increasing and require intensive surveillance. This information would help land managers forecast potential epidemics and make decisions about the need, timing, and methods for control.

New information about the geographic range of the Douglas-fir tussock moth was also gathered by placing hundreds of traps in Oregon, Washington, Idaho, Montana, California, Colorado, New Mexico, Arizona, Utah, and British Columbia. This information will also help identify areas where other insects (such as related tussock moths) are attracted.

The possibility that the sex attractant may be used for direct control is also under study. One way to do this may be to disrupt the reproductive behavior of the moth by permeating the atmosphere with the attractant so male moths cannot find the females. This approach has already been used successfully in field experiments against the gypsy moth and some agricultural pests.

Like most insects, the Douglas-fir tussock moth operates by instinct and reacts to behavioral stimuli. Once a stimulus such as the pheromone has been duplicated it can be used to mainpulate or disrupt the normal life processes of an insect. The use of pheromones is particularly promising since only small quantities are needed, and there appears to be no hazard to other parts of the environment.

end

next "insight" page 155

Human Behavior Aspects of Fish and Wildlife Conservation, by D.R. Potter, K.M. Sharpe, and J.C. Hendee (39)

This annotated bibliography was compiled to aid students, teachers, researchers, conservationists, and managers seeking literature on nonbiological or human behavior aspects of fish and wildlife conservation, including sportsman characteristics, safety, law enforcement, professional and sportsman education, nonconsumptive uses, economics, and history. There are 995 references from 218 different sources. Also included are a list of reference sources used, an author index, and keywords, along with a keyword index.

other

Skiing—"And on Grass Base," by G.O. Klock and W.A. Hampton (40)

Field tests in revegetating ski slopes on Mission Ridge near Wenatchee, Washington, demonstrate that the method of planting is perhaps as important as the choice of seed mixture. It is important to use a starter fertilizer with a fall planting and cover the seed and fertilizer with a thin layer of soil. This practice would also likely be successful on spring plantings, but the inaccessibility of these areas due to snowbanks and wet soil conditions make such plantings impractical.

Mission Ridge—A Case History of Soil Disturbance and Revegetation of a Winter Sports Area Development, by G. Klock (41)

Soil disturbance areas caused by construction of Mission Ridge, a winter sports area, are identified and a review is made of the operator's use of forest research findings to reduce the effects of these disturbances. Soil disturbances were caused by construction of buildings, parking facilities, roads, trails, and summer slope grooming.

A reasonable land use plan by the U.S. Forest Service and the Mission Ridge management provided an excellent recreation area with a minimum impact on the soil resource. The best test for those concerned about the development's effect on the environment would be its effect on the domestic water supply in the lower valley. No change in water quality has been measured, although the county access road poses a potential threat of sedimentation.

The Demand Survey Dilemma: Assessing the Credibility of State Outdoor Recreation Plans, by R. Burdge and J. Hendee (42)

The authors reviewed twelve demand surveys conducted in support of state recreation plans. Recreation use surveys have been conducted for several years in compliance with Land and Water Conservation Act requirements for matching funds. In most states, the second generation of surveys will soon begin. It is not clear that the multimillion dollar investment in recreation surveys has provided accurate information on recreation trends and facilitated more efficient investment in acquisition and development of facilities.

The authors examine the problems encountered in using demand surveys and recommend that future recreation demand surveys be based on random, stratified samples of the general population. *In lieu* of desirable but expensive personal interviews, telephones can be utilized with supplemental personal interviews to include persons with no phones. Carefully prepared interview schedules must be developed with adequate pretesting of both the data collection and analytic procedures. In addition to social and demographic variables, a broad range of outdoor recreation and other leisure activities must be covered including data on where and when it occurs.

Land-Use Planning: A View from Holland, by J. Alan Wagar (43)

Participation in a Dutch planning study suggested that public resource decisions require input from at least five groups: diverse specialists, interest groups, analysts, plan builders, and decision-makers. Integrating these inputs requires emphasizing meanings rather than details, careful distinction between facts and values, and a defensible hierarchy of values. A computer mapping technique for identifying and defining alternatives is described.

Forestry's Response to Increased Demand for Commodity and Amenity Values, by J.C. Hendee (44)

Future demands on forest resources will require more intensive management, emphasizing multiple use. The political support necessary to finance more intensive management will depend on better consensus among various forest clients. Preference for roaded versus unroaded areas obscures the broader range of values desired from each. Three trends with long-range implications include the energy crisis, increasing popularity of commodity activities, and the value of forests as a medium for employment, education, and rehabilitation of people.

Many of the recreational uses of roaded forest land now accrue as an incidental by-product of roads built to harvest timber—but more by accident than by design.

Recreation Insights from Europe, by J.A. Wagar (45)

After a year (1973-1974) spent in The Netherlands, with side trips into England, Switzerland, Germany, France, Belgium, and Liechtenstein, the author describes some important insights gained on European landscape management, interpretation, recreation management, and land-use planning.

recreation - bibliography

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watershed

See also: Research Facilities
Ecosystems, Classification
Silviculture
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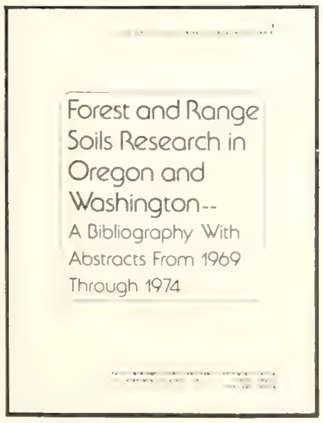
soils, nutrient cycling



Forest and Range Soils Research in Oregon and Washington--
A Bibliography With Abstracts From 1969 Through 1974

Bibliographies

Three bibliographies have been published on soils research under the main title, *Forest and Range Soils Research in Oregon and Washington—A Bibliography With Abstracts.* Reports are available for the following years:

From 1969 Through 1974, compiled by Glen O. Klock (1),

From 1964 Through 1968, compiled by Glen O. Klock (2), and

A Bibliography With Abstracts Through 1964, compiled by Robert F. Tarrant (3).

Note: Terminology used in papers on soils is based on a standard system of soil classification. The reference on that is the 754-page book, *Soil Taxonomy, A Basic System of Soil Classification for Making and Interpreting Soil Surveys,* Agriculture Handbook No. 436, Soil Conservation Service, U.S. Department of Agriculture, December 1975, for sale by the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Price is $17.50; order stock number 001-000-02597-0.

Chemical and Physical Properties of Forest Litter Layers in Central Washington, by David D. Wooldridge (4)

Forest floor layers and their associated microflora and fauna are probably the most dynamic phase of the forest ecosystem and are of great importance in forest land management.

Annual contributions of litter on the forest floor represent a revolving fund of plant nutrients, particularly nitrogen, phosphorus, and sulfur. Forest floors are a food supply and habitat for many soil organisms. These organisms are important in litter decomposition and maintenance of soil physical properties as well as being the active agent in the dynamics of nutrient cycling in forest ecosystems.

This study reports information developed about the physical and chemical properties of forest L, F, and H layers on the east slopes of the Cascades in central Washington.

Evaluating Soil Samples

Soil studies in central Washington indicate that care should be taken in evaluating data from soil samples where the samples are taken at different times. In this study, basalt soils sampled during 1968-69 showed significant periodic variation in cation exchange capacity, pH and Na and K contents. In sandstone soils, cation exchange capacity and Ca, Na, and K content varied significantly among sampling dates.

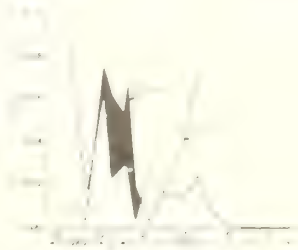
See *Periodic Variation in Physical and Chemical Properties of Two Central Washington Soils,* by Tom D. Anderson and Arthur R. Tiedemann (5).

Nutrient Budget of a Douglas-fir Forest on an Experimental Watershed in Western Oregon, by R.L. Fredriksen (6)

The purpose of this study was to measure the inputs, losses, and retention of plant nutrients on two small watersheds in the H.J. Andrews Experimental Forest. Initial results from one watershed are reported.

Annual loss of nitrogen, phosphorus, silica, and the cations sodium, potassium, calcium, and magnesium followed the same pattern as annual runoff which is heavily dominated by winter rainstorms arising from the Pacific Ocean. Even though a lot of water passed through this ecosystem in the 2 years of the study, the system very effectively conserved nitrogen. In fact, there was a small gain in nitrogen. There were small annual losses of phosphorus and potassium. Calcium, sodium, and magnesium losses were very large with the quantity decreasing in the order given. Silica loss was very high.

Although sediment loss was low during the study period, the loss of nutrients through soil erosion may be of major importance over the long term due to catastrophic erosion events that are few and far between.



Input in precipitation and loss in runoff of dissolved organic nitrogen for each sampling period [illegible]

Soils in Northeastern Oregon

A two-part series describes the chemical characteristics of forest and grassland soils on the Starkey Experimental Forest in the Blue Mountains of northeastern Oregon.

I. *Chemical Characteristics of Some Forest and Grassland Soils of Northeastern Oregon. I. Results From Reference Profile Sampling on the Starkey Experimental Forest and Range,* by Jon M. Geist and Gerald S. Strickler (7)

This paper describes results of chemical analyses of six soil series. Among the forest soils, available phosphorus was consistently much higher in the Tolo profiles. Organic matter and total nitrogen values were comparatively low. Couse and Klicker soils had higher levels of total exchangeable cations than did the Tolo soils.

Only minor differences were noted among grassland soils. However, the Rock Creek soil was quite low in available P.

II. *Chemical Characteristics of Some Forest and Grassland Soils of Northeastern Oregon. II. Progress in Defining Variability in Tolo and Klicker Soils,* by J. Michael Geist (8)

These data establish a firmer data base for virgin soils of the Tolo and Klicker series. The results will be useful in assessing land management impacts on the soil resource.

Comparisons are made of several characteristics of both Tolo and Klicker soils. Results indicate that Tolo soils are generally less fertile. Topsoil conservation practices should be stressed in heavy equipment use on both Tolo and Klicker soils. The data indicate that precautions are necessary in soil sampling, particularly if fertilization guides are to be useful in determining effects of forest management on soil chemical systems.

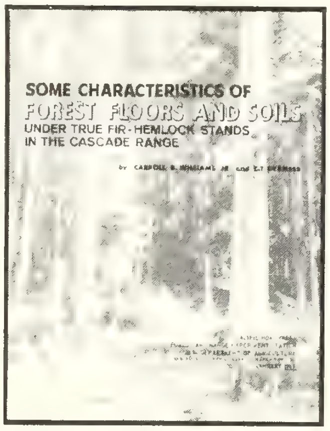
Transpiration of Conifer Seedlings in Relation to Soil Water Potential, by W. Lopushinsky and G.O. Klock (9)

A major factor affecting transpiration is the availability of soil water. This paper compares the transpiration response of five species of conifers, native to the Pacific Northwest, to decreasing soil water potential. The experiments were conducted with 4-year-old seedlings of ponderosa pine, lodgepole pine, Douglas-fir, grand fir, and Englemann spruce.

The results showed that the transpiration rate of ponderosa pine was reduced to a greater degree at intermediate and low levels of soil water potential than that of Douglas-fir. The demonstrated ability of the pines to reduce their rate of water loss to a greater degree than the firs helps to explain the survival of ponderosa and lodgepole pine on relatively dry sites and the presence of the firs on relatively more mesic sites.

Demonstration of differences in transpiration behavior of these species also has significant implication for watershed management: a species which shows a large decrease in rate of water loss when subjected to moderate soil drying should be a more economical user of water than a species in which water loss is less affected by soil drying.

Bill Lopushinsky



SOME CHARACTERISTICS OF
FOREST FLOORS AND SOILS
UNDER TRUE FIR-HEMLOCK STANDS
IN THE CASCADE RANGE

Some Characteristics of Forest Floors and Soils Under True Fir-Hemlock Stands in the Cascade Range, by Carroll B. Williams, Jr., and C.T. Dyrness (10)

An exploratory study in which soils were sampled in 46 undisturbed, old-growth true fir-hemlock stands along the Cascade Range from Diamond Lake in southern Oregon to Mt. Baker in northern Washington. The 46 plots provide a cross section of sites occupied by true fir-hemlock forests.

Results indicate that forest floors under true fir-hemlock stands in Oregon and Washington generally attain only moderate thickness. Nutrient content varied greatly from plot to plot, and there was little apparent correlation between nutrient content and ecological province. Available phosphorus content appeared considerably higher under Pacific silver fir stands, and noble fir forest floors contained more calcium. Otherwise, nutrient content was virtually uniform among forest types. Nutrient levels appear to be adequate for good tree growth, with the possible exception of phosphorus.

Soil Moisture Trends Under Three Different Conditions, by H.G. Herring (11)

A 3-year study of summer soil moisture trends was conducted on the Mission Creek drainage of the Wenatchee National Forest. Soil moisture trends were collected on a grassy opening, a second-growth ponderosa pine stand, and a clearcut plot in the pine stand.

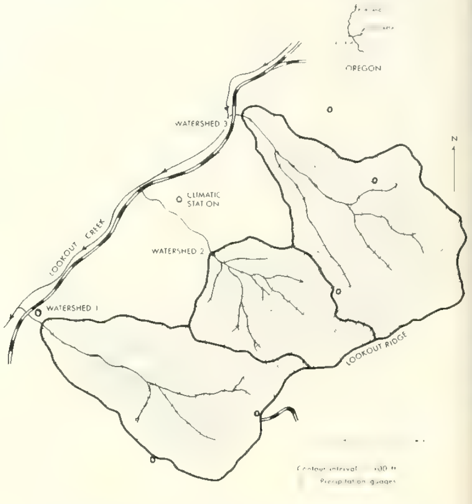
The grassy openings and ponderosa pine stand showed very similar soil moisture regimes except during years of abnormally low winter precipitation and for soils deeper than average for the ponderosa pine zone of north-central Washington. Removing ponderosa pine results in a higher soil moisture content at the end of the growing season.

effects of logging

water quality

Hydrologic and Related Characteristics of Three Small Watersheds in the Oregon Cascades, by J. Rothacher, C.T. Dyrness, and R.L. Fredriksen (12)

Three small study watersheds were established in the H.J. Andrews Experimental Forest in 1952 for study of the quality and quantity of water produced.



In this report, the authors summarize information about geology, soils, vegetation, climate, streamflow, sediment yield, nutrient content, and temperature of streams. Concepts developed serve as benchmarks for watersheds within the Douglas-fir forests on the western slopes of the Oregon Cascade Range. The data collected from these undisturbed watersheds will provide the basis for determining changes that occur as the result of planned timber harvesting.

Timber Production and Water Quality—Progress in Planning for the Bull Run, Portland, Oregon's Municipal Watershed, by R.L. Fredriksen and Richard N. Ross (13)

The Bull Run Municipal Watershed constitutes a cooperative land use planning effort between the City of Portland and the Mt. Hood National Forest. Using this watershed as an example, the authors review information on resource inventories, consider research about land processes, and describe the planning process used to coordinate land capabilities to land use. They conclude by illustrating the land use planning process by presentation of two examples: (a) The Fox Creek Experimental Watershed Study, and (b) the North Fork of the Bull Run River.

The planning process described is new and evolving and must be viewed as continuing. It is being tested along with other approaches in use throughout the country, and evaluation and refinement of the plan must be done. Research will continue to provide better information for developing management prescriptions. Nutrient enrichment, bacteriological quality, and the effect of reservoirs as a source or a sink in planning are areas needing further study.

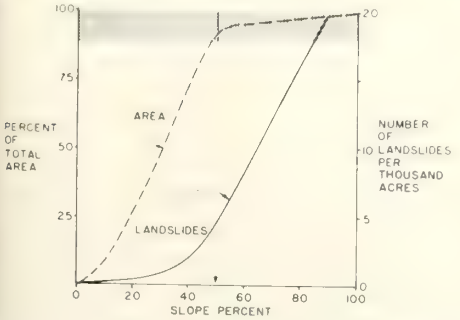
Dick Fredriksen

Impact of Forest Management on Stream Water Quality in Western Oregon, by R.L. Fredriksen (14)

Aspects of water quality and forest management considered by the author include sedimentation, forest fertilization, loss of naturally occurring nutrients, and water temperature. Discussion is presented on how erosion processes deliver soil to streams, how logging increases loss of soil, and how erosion of forests and sedimentation of rivers can be minimized.

Relevant questions about nutrient chemicals in streams are selected and discussed: (a) Do nutrient concentrations in forest streams increase after logging or fertilization? (b) Are the concentrations raised to levels that are toxic to living organisms? (c) Do increased concentrations of nutrients lead to noxious overproduction of aquatic plants?

The author concludes with discussion of the principal impact of elevated stream temperatures and their effects upon resident trout and anadromous fish.

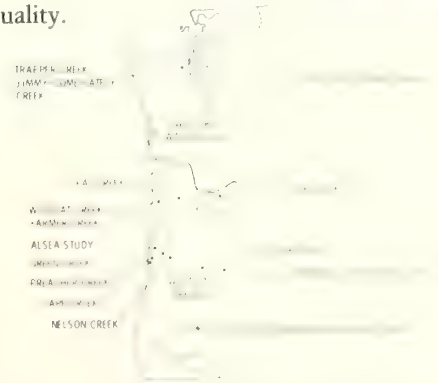


Landslide frequency increases directly with landslopes greater than 50 percent. These steep, actively eroding lands occupy less than 10 percent (shaded area) of the H.J. Andrews Experimental Forest, Oregon.

The Impact of Timber Harvest, Fertilization, and Herbicide Treatment on Stream Water Quality in Western Oregon and Washington, by R.L. Fredriksen, D.G. Moore, and L.A. Norris (15)

This comprehensive review, presented at the Fourth North American Forest Soils Conference in Quebec in 1973, presents concepts about the processes of soil erosion and stream sedimentation, the outflow of native nutrients, fertilizers and herbicides in streams, and illustrates concepts with research findings from experimental watersheds in western Oregon and Washington.

The authors concluded that: (a) Sedimentation of forest streams after timber harvest increases with increasing angle of slope. Roads that cross steeply inclined stream channels cause much greater levels of sedimentation than roads on ridge tops; (b) nutrient loss following clearcutting decreases rapidly with revegetation; (c) nitrogen in streams from forest fertilization does not exceed published standards and the total loss of applied nutrients is relatively small; (d) long-term consequences of repeated forest fertilization must be determined; and (e) drift or direct application of spray materials to surface waters is the principal route of herbicide entry to streams. Overland flow and leaching are relatively unimportant in forest stream pollution. Carefully controlled herbicide applications are not expected to have a significant impact on forest stream quality.



Locations of experimental watersheds in western Oregon and Washington.

AN UNDERGROUND BOOST FOR SEEDLINGS

by Dorothy Bergstrom

Several thousand tree seedlings recently planted by Weyerhaeuser Company in Washington and Oregon are fighting for survival on forest sites where regeneration has been extremely difficult. Researchers are watching them closely to see whether they will establish the new roots they need to survive and grow.

The seedlings, planted in the spring of 1976, are Douglas-fir, ponderosa pine, and western hemlock. Because of research, they may have a chance to become established where others have failed. Before being planted on Weyerhaeuser tree farms, they were given a boost with a specially selected mycorrhizal fungus. The seedlings started life in the laboratories and greenhouses of the PNW Station in Corvallis, Oregon. They grew from seeds planted in containers of vermiculite and peat moss, to which a mycorrhizal fungus had been added.

Mycorrhiza literally means "fungus root." Fungi capable of forming a symbiotic or mutually beneficial relationship with trees are known as mycorrhizal fungi. These fungi form mantles around the roots of plants and assist them in three important ways: (1) they help the roots absorb nutrients and water, (2) they protect the trees from harmful fungi, and (3) they produce growth regulators that foster increased growth and prolong the life of rootlets.

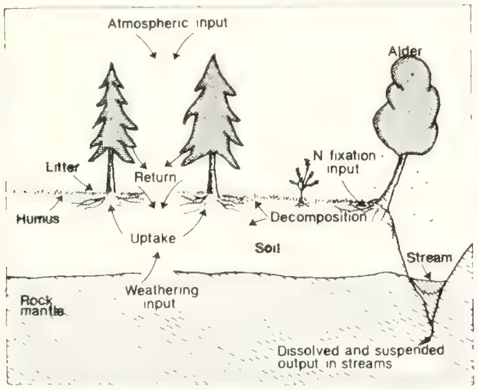
In 1974, Weyerhaeuser and the Pacific Northwest Station began a cooperative study to find out whether reforestation success on hard-to-regenerate sites could be significantly improved by inoculating container-grown seedlings with mycorrhizal fungi. The Weyerhaeuser study was designed by Bratislav Zak, PNW plant pathologist, recently retired. He worked closely with Donald H. Marx, project leader for research on soil-borne organisms at the Southeastern Station, in planning the study. Southeastern Station researchers had successfully introduced mycorrhizal fungi into nursery beds, but no one had tried inoculating seedlings for planting in the Douglas-fir region.

The initial phase of the Northwest study established inoculation methods, growing medium, and fertilizer levels. Then the seeds of ponderosa pine, western hemlock, and Douglas-fir were planted in individual

Comparative Chemical Water Quality—Natural and Disturbed Streams following Logging and Slash Burning, by Richard L. Fredriksen (16)

A comparison of studies on differences in water quality in natural streams and streams disturbed by logging and slash burning showed that loss of nutrient cations increased 1.6 to 3.0 times, following timber harvest and slash burning, when compared with an undisturbed watershed.

A surge of nutrients that followed broadcast burning contained concentrations of ammonia and manganese that exceeded federal water quality standards for a period of 12 days. Annual nitrogen loss following burning averaged 4.6 pounds per acre; 53 percent of this was organic nitrogen contained in sediment. Inorganic nitrogen, dissolved in the stream, made up the remaining part. Annual loss of nitrogen from the undisturbed forest was very small—.16 pound per acre. A review of literature pertinent to the coast Douglas-fir region was included.

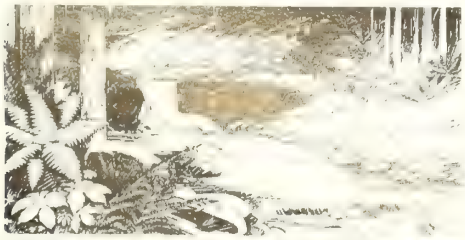


Major elements and processes in a forest ecosystem.

Managing Forest Land for Water Quality, by Jack Rothacher (17)

Water quality management relates to problems of ultimate social importance. Technology is available to control large-scale changes in sediment, temperature, and chemical and bacteriological quality of water from forest land. In many cases, water quality considerations are also economic in terms of maintaining site quality, minimizing road mileage and maintenance, and reducing treatment costs.

In general, managing forest lands for water quality involves a society-oriented attitude on the part of the forest manager in contrast with the traditional economic resource-oriented attitude.



Man-Caused Fluctuations in Quality of Water From Forested Watersheds, by R.F. Tarrant (18)

Forest land managers are beginning to realize the urgent need for water quality standards to measure their success in maintaining a water supply of sufficiently high quality for the great variety of uses to which it may be put downstream. These include domestic water, recreation and esthetics, support of fish and other aquatic life, wildlife, and agricultural and industrial uses.

Man's actions may directly or indirectly cause changes in water quality by altering energy patterns, chemical or physical properties, or abundance of organisms therein. When such changes adversely affect man, we call the phenomenon water pollution.

It is apparent that the changes in energy patterns, chemical or physical constitution, or abundance of organisms in forest waters that do constitute pollution are most often the result of man's activity. Results of research throughout the world indicate also that it is possible for man to enjoy the economic and aesthetic values afforded by forested areas and yet maintain an unpolluted supply of water. The key to producing multiple benefits from the forest, including high quality water, is the amount of care that the forest watershed manager can and will exert in all his activities.

logging roads and erosion

Small Watersheds Studied

In studies on stream sedimentation rates after road construction, timber harvest, and debris burning on the H.J. Andrews Experimental Forest, it was found that minimal deterioration in water quality from sedimentation may be achieved when disturbance from road construction is minimized by reduction of midslope road mileage through use of specially designed yarding systems. Where midslope roads must be constructed across steep sideslope or headwall areas, all knowledge available to the engineer should be used to stabilize roads. In the logging operation, every effort should be made to minimize disturbance to the streambed by keeping slash and debris out of streams.

See *Erosion and Sedimentation Following Road Construction and Timber Harvest on Unstable Soils in Three Small Western Oregon Watersheds,* by R.L. Fredriksen (19).

Impact of Clearcutting and Road Construction

To compare the impacts of clearcutting and road construction on soil erosion by landslides, the H.J. Andrews Experimental Forest was divided into two zones of approximately equal area. The zones, one stable and one unstable, had strikingly different susceptibilities to erosion by rapid soil movements.

Since logging and road cutting began in 1950, only two small road-related slides have taken place in the stable zone. In contrast, the unstable zone has been the site of 139 slides during the same period.

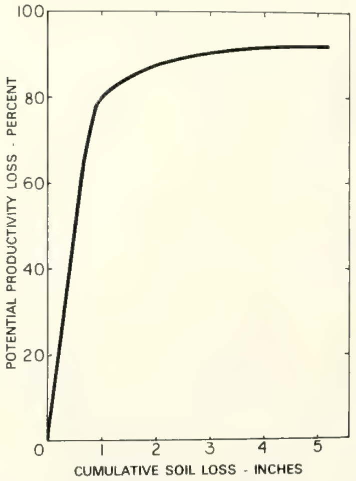
When road impact is assessed at a level of development comparable to timber cutting, roads contribute about half of the total management impact. The combined impact of roads and clearcut logging has constituted a five-fold increase in landslide erosion relative to undisturbed forested areas.

See *Impact of Clear-Cutting and Road Construction on Soil Erosion by Landslides in the Western Cascade Range, Oregon,* by F.J. Swanson and C.T. Dyrness (20).

Estimating Two Indirect Logging Costs Caused by Accelerated Erosion, by G.O. Klock (21)

Indirect costs of onsite and downstream damages due to logging operations were analyzed for their potential use in hypothetical erosion assessment models.

By using the soil erosion potential for several yarding systems to determine the erosion assessments, total relative logging costs for each system may be evaluated. This evaluation method may show that environmentally acceptable advanced systems of yarding could cost less than traditional yarding systems at some locations.



Potential productivity loss as a function of cumulative surface soil loss.

actors Affecting Mass Movement of Four Soils in the Western Cascades of Oregon, by R.C. Paeth, M.E. Harward, E.G. Knox, and C.T. Dyrness (22)

our soils derived from tuffaceous rock in he western Cascades were studied to determine relationships to slope stability. The tudy was undertaken to determine physical, hemical, and mineralogical properties of he four soils in order to understand why oils formed on greenish tuff and breccia vere more prone to mass soil movements han soils formed on yellowish and reddish uff and breccia.

Soils prone to slope failure were characterized by high amounts of smectite clay, absence of kaolin, and moderate amounts of free iron oxide. The more stable soils contained kaolin, more chlorite and chloritic intergrades, less smectite, and higher amounts of free iron oxide.

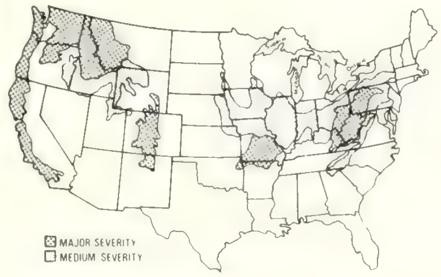
While all four soils contained appreciable amounts of clay, there was no consistent relationship between clay content by mechanical analysis and stability of the soils on slopes. Soil and rock colors, however, seem to provide a local field guide for prediction of clay mineralogy and relative landscape stability.

udging Impact and Damage of Timber Harvesting to Forest Soils in Mountainous Regions of Western North America, by Douglas N. Swanston (23)

lope disturbance produced by forest operations in mountainous regions has been learly identified as a major contributor to ccelerated soil mass movements. Roaduilding is the most damaging operation, ut timber cutting and slash burning have lso been shown to be significant initiators f mass erosion activity.

ince timber harvesting is a major economic ctivity in mountainous areas and is rapidly dvancing onto increasingly unstable terain, it is essential that the land manager be ble to recognize potential problem zones nd identify major factors contributing to nstability.

There are two main options available to the and manager. He can: (a) identify problem areas and avoid operations on unstable terrain, or (b) identify and attempt to control operational effects. In highly unstable areas or areas of questionable economic value, avoidance of all operations is probably the best and least expensive solution. Controlling operational effects is a much more difficult approach which at best will probably be only partially successful. It is applicable in high value areas of questionable soil stability or where other considerations override a desire for stability maintenance.



Map of aerial extent and severity of landslide problems in the United States.

Principal Soil Movement Processes Influenced by Road-Building, Logging and Fire, by Douglas N. Swanston (24)

Studies on watersheds of the Intermountain and Pacific Coast States indicate that there are four dominant natural soil mass movement processes active (listed in order of decreasing importance and regional frequency of occurrence): (a) debris avalanches, debris flows and debris torrents; (b) slumps and earth flows; (c) deep-seated soil creep; and (d) dry creep and sliding. Roadbuilding, logging and fire play an important part in initiation and acceleration of the four kinds of soil mass movements.

Roadbuilding stands out at the present time as the most damaging activity, with soil failures resulting largely from slope loading, back-slope cutting, and inadequate slope drainage. Logging and fire affect stability primarily through destruction of natural mechanical support for the soils, removal of surface cover, and obstruction of main drainage channels by debris.

logging and streamflow

Does Harvest in West Slope Douglas-fir Increase Peak Flow in Small Forest Streams? by Jack Rothacher (25)

Studies on the H.J. Andrews Experimental Forest indicate that timber harvest by overhead cable (in situations where logging roads occupy no more than 6 percent of the drainage) has only a minor effect on major peak streamflows which occur when soils are thoroughly wet. Exceptions are the early fall storms following the dry summers characteristic of the west coast climate. At this time, peak streamflow from unlogged areas may be less than in the harvested area because the soil in the unlogged area is drier and has greater moisture storage capacity than in the harvested area. These early fall storms rarely result in major peak streamflows.

containers of vermiculite and peat moss inoculated with a pure culture of one of four species of mycorrhizal fungi. The fungi, isolated in the laboratory from fresh mushrooms, were selected because they are widely distributed in western forests and can be grown in laboratory cultures. One of the species is prominent in Douglas-fir forests; the other three are commonly found under ponderosa pine and western hemlock as well as Douglas-fir.

The seedlings grew in their containers in the Corvallis lathhouses for about 6 months before they were planted on Weyerhaeuser tree farms near Mount St. Helens, Washington, and Klamath Falls, Oregon.

Before the study is completed, several thousand more seedlings will be inoculated with other fungi before being planted. When measurements of seedling survival and growth on the tree farms are completed in 1978, researchers will be able to tell foresters which of the mycorrhizal fungi tested best aid seedling establishment on hard-to-regenerate sites in Northwest forests.

Although the concept of mycorrhizae was advanced as early as 1842, Mycologist Jim Trappe, project leader for research in tree root symbiosis and current director of the Weyerhaeuser study, has found that it is not generally well understood by foresters and others who are responsible for reforestation programs.

Researchers have known for some time that all economically important forest trees and most forage plants need mycorrhizae for survival and satisfactory growth.

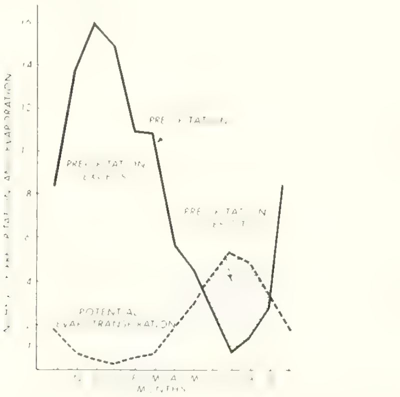
The importance of mycorrhizae has been demonstrated by the failure of exotic trees to flourish when planted in distant parts of the world. However, when suitable mycorrhizal fungi have been added to nurseries or planting sites, the survival and growth of these trees have improved dramatically. Similarly, on mining spoils, areas never forested, or those where trees have been absent for a long time, naturally seeded plants usually die unless spores of mycorrhizal fungi carried by air or animals are washed into the soil.

In the forest, mycorrhizae develop when the growing roots of a seedling encounter spores or mycelium of mycorrhizal fungi. The spores germinate and the growing fungi surround the roots. However, if this process is

Regimes of Streamflow and Their Modification by Logging, by Jack Rothacher (26)

In the H.J. Andrews Experimental Forest, measurements of changes in streamflow from clearcutting and partial cutting on old-growth Douglas-fir forests were compared with data on precipitation, evapotranspiration, soil moisture, and seasonal streamflows to determine if stream regimes and their fish resources are significantly altered by logging.

It was concluded that although timber harvest may influence the stream environment in a number of ways, evidence to date suggests that any modification in streamflow regime is probably generally beneficial to the fishery, at least on the west slope. More water flows in the streams all year long; major flood flows are apparently not markedly increased; minimum streamflow during dry summers is materially increased. In the majority of cases, changes in streamflow resulting from vegetation manipulation will probably be much less than the normal climatic variation.



Mean monthly precipitation and evapotranspiration.

High Yield From the Bull Run Watershed, by L.V. Luchin (27)

Measurements on the Bull Run watershed were made to determine whether water production is higher or lower than should be expected when comparing actual discharge with computed yields.

It was found that other than by removing vegetation to decrease interception and transpiration, no means of substantially increasing water yields from Bull Run watershed appear to be feasible. Furthermore, it is important to note that the feasibility of increasing water yields through removal of vegetative cover has been considered purely from a physical standpoint. The removal of vegetative cover from areas of the watershed will affect other resources such as wildlife, soils, water quality, and esthetics. Before attempting large-scale increases in water yields, watershed managers must determine the effect of the proposed actions upon other watershed resources.

Forest Land Use and Streamflow in Central Oregon, by H.W. Berndt and G.W. Swank (28)

In this case study of Ochoco Creek, the hydrologic performance of a 295-square mile drainage in central Oregon was compared with the land use history for the period 1921-65. Two distinct changes in streamflow regimen were identified. The first, beginning about water year 1942, was an increase of 2.21 inches in average annual yield. The timing of this increase is approximately coincident with the onset of timber harvesting activity in the basin. The second change was a decrease of 1.18 inches in average water yield beginning about 1958. This change could possibly be related to the full stocking of cutover lands by dense, second-growth stands and a general reduction of timber harvest activity.

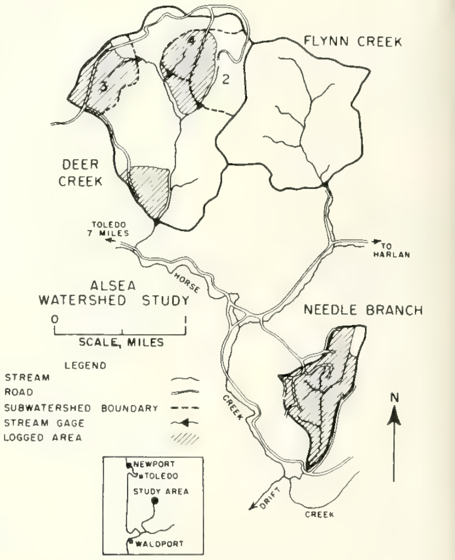
Though more sensitive, refined tests of the influence of timber harvest on water yield are needed for stands east of the Cascade Range, the analyses in this report show that accepted management practices for vegetative types found on Ochoco Creek have favored water yields.

Changes in Storm Hydrographs After Road Building and Clear-Cutting in the Oregon Coast Range, by R.D. Harr, W.C. Harper, J.T. Krygier, and F.S. Hsieh (29)

Six small watersheds in the Oregon Coast Range were studied and data gathered on changes in storm hydrographs after road building, clearcutting, and burning. It was found that peak flows increased significantly after road building, but only when roads occupied at least 12 percent of the watershed.

Roads had no detectable effect on volumes of storm hydrographs. By reducing transpiration and interception, partial clearcutting increased peak flow, quick flow, delayed flow, and total storm hydrograph volume of some streams. Most increases were largest in the fall when maximum differences in soil water content existed between cut and uncut watersheds.

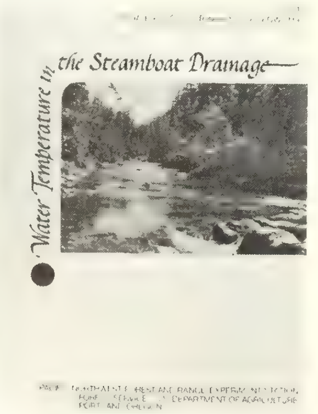
The effect of roads on peak flows has significance for design of culverts and bridges in headwater areas, but probably does not influence downstream flooding. Increases in streamflow after clearcutting should have no appreciable effect on either damage to bridges and culverts in headwater areas or downstream flooding. Caution must be used in extending results of this study to storm runoff events of low frequency and large magnitude.

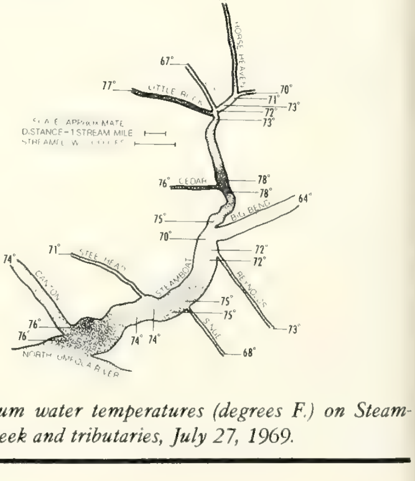


Watersheds in the Alsea watershed study.

Water Temperature in the Steamboat Drainage, by George W. Brown, Gerald W. Swank, and Jack Rothacher (30)

Stream temperatures were studied in the Steamboat drainage in the North Fork of the Umpqua in Oregon. Logging operations in this area are typical of much of the commercial forests on the west slopes of the Cascade Range. Changes in water temperature of tributary streams influenced by various degrees of exposure from logging were measured, and a simplified prediction equation was tested.


Water Temperature in the Steamboat Drainage



Maximum water temperatures (degrees F.) on Steamboat Creek and tributaries, July 27, 1969.

slope stability problems

Stability of Steep Land, by D.N. Swanston and C.T. Dyrness (31)

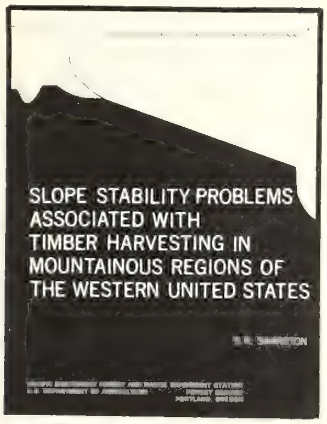
One of the most important factors affecting stability of steeply sloping terrain is disturbance. As a general rule, with increasing disturbance comes increasing erosion. The actual erosion processes include both surface erosion and mass soil movement.

On-site erosion reduces site productivity by removing soil material and lowering nutrient capital available for plant growth. The resulting soil and debris causes damage to roads and other improvements, ranging from roadblocks by landslide debris to houses buried by mudslides.

Continuing instability may cause difficulty in reestablishing protective vegetation and tree seedlings.

Downstream effects include lowering of water quality by increased sediment and dissolved chemical content; shortened life span of reservoirs due to excessive siltation; and degradation of fish habitat through increased sediment in spawning gravels and blockage of fish passage by landslides.

Reduction in landslide incidence is best approached through improved road design and construction and planting vegetation to stabilize disturbed areas. Some effective road design and construction techniques are already available to the engineer and land manager; it is their successful application which will determine the final impact.



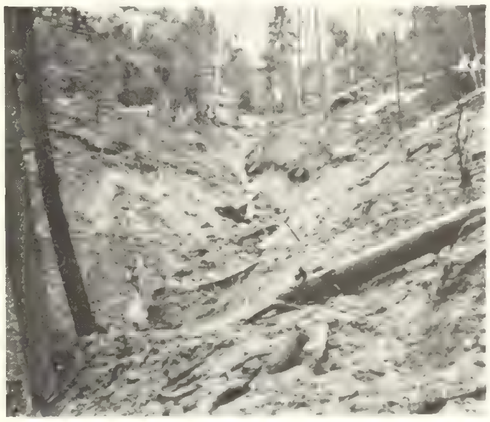
SLOPE STABILITY PROBLEMS ASSOCIATED WITH TIMBER HARVESTING IN MOUNTAINOUS REGIONS OF THE WESTERN UNITED STATES

D.N. SWANSTON

Slope Stability Problems Associated With Timber Harvesting in Mountainous Regions of the Western United States, by D.N. Swanston (32)

As forest operations shift to steeper slopes, they play an increasing role in initiation and acceleration of soil mass movements. Logging operations create major problems through (a) destruction of roots, the natural mechanical support of slope soils, (b) disruption of surface vegetation cover which alters soil water distribution, and (c) obstruction of main drainage channels by logging debris. Road building stands out at the present time as the most damaging operation with soil failures resulting largely from slope loading (from road fill and sidecasting), oversteepened back cuts, and inadequate provision for slope and road drainage.

At the present time, attempts at prevention and control are limited to identification and avoidance of highly unstable areas and development and implementation of timber harvesting techniques least damaging to natural slope stability.



Debris torrent developed in an intermittent stream channel along the South Fork of the Salmon River in Idaho. Initial failure occurred in road fill near the ridgetop.

Doug Swanston

Soil Moisture Tension Variation on Cutovers in Southwestern Oregon, by William E. Hallin (33)

Three study areas, Calf Creek, South Umpqua, and Dead Indian, in southwestern Oregon were examined for purposes of collecting data on soil moisture tensions. From these data, the author reports on characteristics of soil moisture retention for several southwestern Oregon forest soils; describes variation in soil retention in relation to parent material, aspect, depth, clay content; and compares soils moisture tension on cutovers with and without vegetation during the driest part of the growing season. Soil texture is also discussed to characterize the study soils.

delayed, a seedling's roots may be invaded by harmful fungi. If the seedling survives, it may be stunted. Some seedlings will grow without mycorrhizae in the nursery, provided they are given sufficient nutrients and pathogens are controlled. But, when seedlings are planted in the forest, the mycorrhizae are essential.

Researchers have also found that mycorrhizal fungi vary in their environmental requirements. Some tolerate a wide range of conditions; others do not. Mycorrhizal fungi may unite with roots of seedlings growing in nursery beds, but if these fungi are not adapted to the sites where the seedlings are planted, they may not function or may even die. If that happens, the seedlings also will die unless they contact mycorrhizal fungi native to the planting site soil.

The ways mycorrhizal fungi reproduce are significant for forest management. Although most mycorrhizal fungi live in the upper few inches of soil, some surface to reproduce. Miniature mushrooms and toadstools are formed underground. At the proper stage of development, they suddenly take on water and push their way through the soil surface to expand and discharge their spores. The spores are carried by the wind and washed back into the soil by rain. Other species, such as truffles, reproduce underground. Small animals, attracted by the odor of the truffles, eat the fruiting bodies, but, the spores are not digested and are excreted in their fecal pellets. Squirrels, mice, and voles traveling from forested areas to newly planted clearcuts distribute spores of fungi to the benefit of new seedlings.

Several forest management practices deplete mycorrhizal fungi in the soil, Trappe says. The most important are elimination of host plants and drastic soil disturbance. Heavy timber cutting and slash burning can reduce fungi populations. Some pesticides may also destroy them. Eliminating truffle-eating small animals from newly planted areas is likely to reduce the number of fungal spores available for forming mycorrhizae.

Until the ecology of mycorrhizae is better understood, researchers will not be able to recommend changes in forest management practices. However, if seedlings can be supplied with suitable fungi before they are planted, the depletion of local fungi by management practices will not be of critical importance. Much remains to be learned about mycorrhizae, especially in forestry

roadside stabilization

Response of *Penstemon fruticosus* to Fertilization, by G.O. Klock (34)

Bush penstemon is an attractive native ground cover frequently found on recently logged areas and new roadbank cuts on the east slopes of the Cascade Range in Washington. It is easily identified by its brilliant blue-lavender to light purplish flowers in the early spring.

This plant is apparently able to survive under conditions of low fertility and drought. It reproduces by seed and spreads across open ground by prolific layering. Rate of spread appears to be fairly slow, and since it is most frequently found growing on poor soils such as roadbanks, it might be that fertilization could hasten growth. A greenhouse fertilization study indicates that bush penstemon does respond to nitrogen and phosphorus fertilization. With adequate soil moisture, 50- to 100-ppm nitrogen is sufficient for nearly maximum growth.

Stabilization of Newly Constructed Road Backslopes by Mulch and Grass-Legume Treatments, by C.T. Dyrness (35)

Six different treatments to control erosion along roadsides were studied. Both grasses and legumes were tested, with all treatments showing beneficial results.

Considerable evidence has accumulated to indicate the desirability of treating newly constructed roadside slopes in the early fall before heavy rains. Most important is that the loose, unprotected soil is most vulnerable to erosion during this period. In addition, mulching of backslopes may be necessary to keep soil loss to a minimum during the first few critical months following road construction.

Ted Dyrness

Grass-Legume Mixtures for Erosion Control Along Forest Roads in Western Oregon, by C.T. Dyrness (36)

Continued study of roadside seeding to control erosion in the mountains of western Oregon provides the following information:

- Legumes are unable to compete with grasses and tend to disappear from most roadside stands after 1 year.

- Erosion can be halted by using grass-legume seed, fertilizer, and straw mulch.

- Erosion is greater on recently disturbed slopes than from backslopes that have been bare for several years.

- Mulches should be used, along with seeding, to minimize erosion during the first rainy season following road construction.

- Infertile subsoils failed to maintain a viable vegetative cover and required refertilization 7 years after the plots were initially seeded and fertilized.

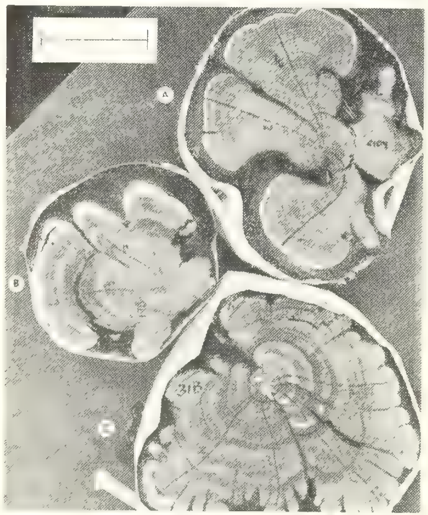
- Bare, unprotected roadside slopes continued to erode at a rather constant rate, or at about .2 inches of soil per year, during the course of the study.

For additional information on this subject, see also older publications listed in the bibliography (37).

effects of irrigation

Effect of Large-Scale Irrigation on Climate in the Columbia Basin, by W.B. Fowler and J.D. Helvey (38)

Charles K. Stidd claimed in 1967 that evaporation of irrigation water from the Columbia Basin caused a significant increase in precipitation over the basin and surrounding area. Forest Service scientists, however, do not agree. Information for this report, which appeared in *Science* magazine in 1974, was gathered by studying weather records and by examining cross sections of sagebrush, a desert shrub which is very sensitive to moisture changes in the environment.



Sections of sagebrush: A, from a control site; B, from an irrigated site; and C, from an irrigated site. Scale bar, 3 cm.

Bill Fowler

Irrigation Increases Rainfall? by Charles K. Stidd, William B. Fowler, and J.D. Helvey (39)

The article listed above by Fowler and Helvey added fuel to the scientific arguments over the climatic effects of irrigation. This later article (also in *Science*), by Stidd, Fowler, and Helvey, debates the subject further.

Stidd tested data available for 7 years since 1966, and found that his original claim—that irrigation does affect precipitation—was strengthened. Fowler and Helvey respond with technical arguments in a rejoinder which, they claim, confirms **their** earlier contention that irrigation does not increase rainfall in the Basin. They point out that a period selected by Stidd as ''normal'' was actually a period of widespread drought, especially in the Columbia Basin.

Fowler and Helvey feel it is important to resolve the issue. If continuing irrigation increases precipitation over the irrigated area, it would have far-reaching implications for land-use and water resources planning. They expect to compare results from the Columbia Basin with those from other large irrigated areas. More will undoubtedly be heard on this subject.

entiat experimental forest

Operation Phoenix, Forest Hydrology Laboratory, Wenatchee, Washington (40)

This pamphlet briefly traces the history of major research studies conducted on the Entiat Experimental Forest near Wenatchee by scientists from the Forest Hydrology Laboratory.

From 1959 to 1970, studies in the three watersheds of the experimental forest were mainly directed at ways of improving water quality and yield from eastern Cascade forests. In August of 1970, wildfire destroyed the experimental forest and thousands of surrounding acres. The fire halted or seriously impaired studies in progress and necessitated that the scientists define new directions for research. "Operation Phoenix," named for the mythical bird which was reborn from its own ashes, is this new research program.

The new program is designed to study the effects of fire on watersheds and to evaluate ways of rehabilitating them. Research includes studies of the environmental effects of logging systems devoted to salvage wherein nutrient and soil loss, degree of damage to successional plants, soil disturbance, and stream sedimentation are monitored for each system.

The three watersheds on the Entiat Experimental Forest, Fox, McCree, and Burns Creeks, were divided into three separate research zones, each receiving a different type of experimental treatment. A fourth, and adjacent watershed, Brennegan Creek, was also included within the study area.

Fox Creek, the original control watershed before the fire, was left untouched. No seed or fertilizer has been applied here and no roads have been built. The scientists use this watershed to study the ways in which nature, uninfluenced by man, reacts to wild fire. In this watershed they have found that snowbrush ceanothus sprouts one month after the fire, provides natural ground cover and fixes atmospheric nitrogen, helping to restore nutrients to the soil.

The McCree Creek watershed was treated with a high nitrogen urea fertilizer. Burns Creek received ammonium sulfate, and Brennegan Creek was left unfertilized. McCree, Burns, and Brennegan watersheds were then seeded with orchardgrass, hard fescue, Drummond timothy, perennial ryegrass, and yellow sweet clover.

In general, the scientists found that the locations treated with both fertilizer and seed had higher plant productivity, less erosion, and higher stream nutrient levels. The ground cover on Brennegan Creek was similar to that on the seeded and fertilized watersheds, but plant productivity and health was lower. The scientists found that orchardgrass and hard fescue produced the best results.

Perhaps the most dramatic effects noted on the Entiat were changes in water yield. Flows from denuded slopes almost doubled during the first year after the fire and heavy precipitation in the second year caused an increase in water yield four to five times above normal. The greatest erosion noted was caused by massive debris flows coupled with high precipitation.

Studies on Entiat watersheds should continue to provide answers about the long-term impacts of fire on forest ecosystems east of the Cascade Mountains.

Climate and Hydrology of the Entiat Experimental Forest Watersheds Under Virgin Forest Cover, by J.D. Helvey, W.B. Fowler, G.O. Klock, and A.R. Tiedemann (41)

This publication presents detail on conditions existing in the three watersheds of the Entiat Experimental Forest before the wildfire of August 1970. Described are watershed conditions with respect to location, topography, soils, vegetation, precipitation, and the patterns, temperature, and chemistry of streamflow. These data are a useful addition to hydrologic information collected from small, undisturbed watersheds throughout the United States. The paper also serves as a reference, and detailed information presented need not be repeated in future reports which describe postfire conditions.

The part of the forest ecosystem that exists above ground has been studied in great detail. Much less is known about the underground organisms (roots, animals, and microorganisms), even though their biomass is as great as that above ground and as important. For example, most plants have been adequately classified, but many mycorrhizal fungi have not and cannot even be identified. Trappe believes that classification is vital to research and is now devoting part of his time to this essential task.

The Pacific Northwest Station is one of several public agencies in Corvallis now engaged in mycorrhizae research. Others include the Ornamentals Laboratory of the Agricultural Research Service and the Departments of Botany and Plant Pathology, Horticulture, Soils, and Forestry at Oregon State University. In May 1976, the university, in collaboration with the Pacific Northwest Station, received a grant of $146,000 from the National Science Foundation for a 2-year study of the role of mycorrhizal fungi in nutrient capture and cycling in Douglas-fir ecosystems.

At present, probably more people are involved in mycorrhizae research in Corvallis than anywhere in the world. "It is important that a sizable portion of forestry research be devoted to figuring out how a forest works," Trappe says, "because such knowledge will lead to better forest management practices."

end

STUDYING FIRE IN THE INTERIOR

by Louise Parker

A June storm rolls in over the mountains, dropping lightning bolts into the dry forest. A tiny stream of smoke curls up and in minutes several trees are ablaze. Soon, a whole hillside is covered with smoke.

With luck, the fire has been spotted within a few minutes of its start, and reported. A Bureau of Land Management crew, dispatched from the nearest smokejumper center, is quickly on the way.

It is a scene repeated many times in the Western United States during the summer months. But this time the scene is interior Alaska.

Early Effects of Forest Fire on Streamflow Characteristics, by H.W. Berndt (42)

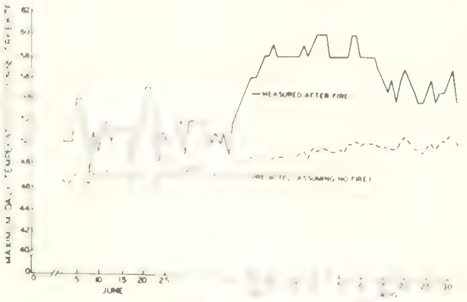
Comparison of streamflow records from three small mountain streams before, during, and after the August 1970 wildfire showed three immediate effects of destructive burning on the Entiat Experimental Forest.

First, flow rate was greatly reduced while the fire was actively burning. Second, destruction of vegetation in the riparian zone reduced the daily variation of flow rates. And third, flow rates increased to levels above extended normal depletion curves, but to varying degrees between watersheds. No drastic immediate change in stream temperatures was noted during the studies.

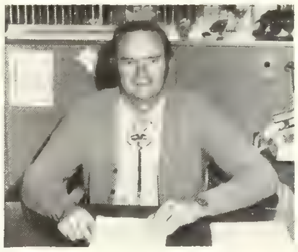
Dave Helvey

First-Year Effects of Wildfire on Water Yield and Stream Temperature in North-Central Washington, by J.D. Helvey (43)

Records of flows from the three Entiat watersheds had been kept for 9 years before the 1970 fire. These were used as control data to determine the first-year effects of the fire on water yield and stream temperatures in the experimental forest. Water yield increases (averaging 3.5 inches) due to the effects of the fire, apparently came during spring snowmelt and the summer months. During late summer when streams were exposed to direct sunlight, maximum daily stream temperature increased by as much as 10° F. The study is continuing so that the transition back to forest vegetation can be related to changes in water yield, stream temperature, and other hydrologic factors.



Measured temperature in [illegible] July, and August 1971, and expected values, assuming the forest had not been destroyed by fire.



Art Tiedemann

First-Year Vegetation After Fire, Reseeding, and Fertilization on the Entiat Experimental Forest, by A.R. Tiedemann and G.O. Klock (44)

Regrowth and successional patterns of native plant species were evaluated after fire, reseeding and fertilization, using two different sources of nitrogen and one of sulfur.

Comparisons between seeded watersheds and the unseeded, unfertilized control indicate that erosion-control seeding improved first-year vegetative cover by up to one-third. Of the seeded species, orchard grass, hard fescue, and timothy provided most of the first-year cover. Perennial rye and yellow sweetclover showed poor development.

Effectiveness of fertilizer was questionable the first year since total cover on the seeded-only watershed was nearly as great as on the watershed seeded and fertilized with ammonium sulfate and greater than on the watershed seeded and fertilized with urea. However, observations in the early summer of 1972 indicate that vegetal cover on the fertilized watersheds is substantially higher than on the control or seeded-only watershed. Also, vigor of seeded species appears to be much better on the fertilized watersheds.

Streamflow Nitrogen Loss Following Forest Erosion Control Fertilization, by G.O. Klock (45)

Nitrogen monitoring studies on streams of the three watersheds of the Entiat were made after initiation of an erosion control reseeding program designed to offset the effects of the wildfire of 1970. In the reseeding program, two of the watersheds were fertilized, one with urea and the other with ammonium sulfate. The third watershed was retained as an unrehabilitated control.

For a 60-day period during and following fertilization, 1.37 kilograms of urea-N and 2.90 kilograms of nitrate-N were estimated to have been carried by streamflow from the watershed fertilized with 27.5 metric tons of elemental nitrogen as urea. On the watershed fertilized with 33.16 metric tons of elemental nitrogen as ammonium sulfate, 1.45 kilograms of nitrate-N were estimated to have been transported from the watershed by streamflow.

Stream Chemistry Following a Forest Fire and Urea Fertilization in North-Central Washington, by A.R. Tiedemann (46)

The stream chemistry of Grade, Camas, and Falls Creeks on the slopes north of Lake Chelan was monitored to determine the impact of urea fertilizer on water flowing from an area that was burned by wildfire in July of 1970.

After the fire, the area had been seeded with grasses and legumes and fertilized with urea to help prevent soil erosion and restore soil-plant nutrient cycles. Since the creeks draining the area are a source of municipal water, the U.S. Forest Service, administrator of these lands, was concerned that nitrate-N and ammonia-N, which are derived from urea fertilizer, might exceed permissible limits.

It was found that the quality of water for municipal use from watersheds involved in the fire does not appear to be threatened by either burning or urea fertilization during the first and second year after these treatments. Even though urea fertilization after fire at 78 kg./ha. apparently caused immediate and protracted increases in nitrate-N levels, the maximum observed level of 0.31 p.p.m. poses no hazard. This value is 30 times less than the proposed permissible level.

It is not likely that losses of nitrate-N in streamflow are substantial enough to affect future productivity of these ecosystems.

Impact of Five Postfire Salvage Logging Systems on Soils and Vegetation, by Glen O. Klock (47)

Impacts of five traditional and advanced logging systems were compared under postfire salvage conditions on the east slope of the Cascades.

Traditional systems included tractor skidding over bare ground and cable skidding. Advanced systems included skyline, helicopter, and tractor skidding over snow. It was found that traditional logging systems caused more severe soil surface disturbance and consequent erosion than advanced systems.

System	*Total Logged Area (%)*	*Number of Sample Plots*
Helicopter	48.8	1,336
Tractor skidding on snow	24.2	534
Tractor skidding on bare ground	4.0	279
Cable skidding	20.1	497
Skyline	2.9	255

Percent of study area harvested by each yarding system and number of sample plots within each individual area.

Wildfire Effects on Nutrient Distribution and Leaching in a Coniferous Ecosystem, by Charles C. Grier (48)

Results of experiments indicate that the Entiat fire had a substantial effect on the nutrient status of this forest ecosystem. These effects included large nutrient losses during the fire, rapid leaching of mineralized cations into the soil after the fire, and reention of large amounts of these cations by he soil. The study was designed to (a) estimate nutrient losses during the fire; (b) deermine the average chemical composition and amount of surface ash; (c) directly measure quantities of certain nutrients eached from ash during the first year after he fire; and (d) examine patterns of nutrient retention by the soil.

Erosion Control Fertilization—From Pot Study to Field Testing, by G.O. Klock, J.M. Geist, and A.R. Tiedemann (49)

In the Entiat Experimental Forest, a study was conducted to determine why reseeding with orchardgrass met with limited success when nitrogen was used as an initial fertilizer in the rehabilitation program.

The study was designed to test the hypothesis that sulphur deficiency may be limiting vegetative establishment when nitrogen fertilizers are used. Results suggest that sulphur fertilization is also important and that further research is needed to compare nitrogen-sulphur fertilization with nitrogen fertilization alone.

Seeding Recommendations for Disturbed Mountain Slopes in North Central Washington, by G.O. Klock, A.R. Tiedemann, and W. Lopushinsky (50)

Firelines constructed in 1970 to control wildfire in the Wenatchee and Okanogan National Forests were reseeded in 1971 in four study locations.

Forty plant species were seeded on plots in the firelines and fertilizer applied as a secondary treatment. The four study locations were Dinkelman Ridge, Sugarloaf Corral, Handy Springs, and Silver Creek.

Results of the study show that firelines with severely disturbed soil can be successfully revegetated by artificial seeding on east Cascade upper slopes of north central Washington. Later orchardgrass, Drummond timothy, perennial ryegrass, Manchar smooth brome, and tall fescue proved to be the best adapted species for this purpose.

Limited success with mixtures of species, whether perennial or perennial-annual, indicates that the best ground cover will probably be achieved with one or two of the above selected species. A starter fertilizer treatment is imperative. Covering the seed by methods such as with a seed drill or harrowing and using mulches, particularly at higher elevations, can be expected to increase the level of success.

Glen Klock

Watershed Behavior After Forest Fire in Washington, by J.D. Helvey (51)

Research results are summarized for the first postfire year after the Entiat burn of 1970. Presented are recent findings on water yield and information on soil movement and channel cutting since the fire.

Hydrologic behavior in 1972 was in sharp contrast to prefire conditions but was confounded by several factors, and the effects of a single factor could not be determined. For example, the effect on runoff of reduced evapotranspiration caused by destruction of the vegetation by fire was confounded by abnormally high precipitation. Other factors include logging road construction, logging over snow, and intense summer rainstorms.

The total effect of road building and logging on the occurrence or severity of these debris torrents could not be determined. However, massive torrents occurred on Fox watershed which was burned but remains unroaded and unlogged. Lake Creek watershed which joins the western boundary of Fox watershed was not burned or logged, and it remains stable. An allauvial fan at the mouth of almost every tributary of Entiat River testifies to the occurrence of these events over past centuries, long before man began harvesting timber. If road building and logging on the experimental watersheds had an effect, it was probably minor compared with the effects of fire and subsequent record precipitation amounts.

The fact that debris torrents and the associated channel cutting occurred on Fox and McCree Creeks but not so much on Burns may indicate that the rehabilitation program applied to Burns watershed was more successful. Although such a conclusion is plausible, it is too early to know for sure. Future studies may reveal a relationship between hydrologic behavior differences of these watersheds and differences in their geology, geomorphology, or both. Meanwhile studies are underway to monitor trends of vegetation development on all three drainages and to relate vegetation density to soil movement and water yield.

Alaska's great interior is a very special environment. A land of great mountain ranges, snow, ice, and glaciers, it is also a land of great river systems—the Yukon, Copper, Susitna, Kobuk, and Kuskokwim. There are also lowlands, rolling hills, and wide expanses of forest.

Fire is an ever-present part of the environment of the interior. It has been a part of the ecosystem for the past several thousand years. As a result, the vegetation is a subtle mosaic that includes mixtures of birch, poplar, and cottonwood trees, black and white spruce, and recently burned areas that are just beginning to recover from fire.

The Bureau of Land Management manages most of the interior stretching from the Alaska Range north to Prudhoe Bay, an area of about 172 million acres. The BLM's Alaska Fire Control Service was established in 1946, with the charter to extinguish all fires. More recently, a new management policy for BLM in Alaska requires initial attack on all fires. Then, if a particularly hot fire eludes control, a top-level management team evaluates the situation. Today, in some cases, a decision may be made to let the fire burn itself out naturally. Although this policy is still controversial in other parts of the United States, it makes sense in Alaska's interior, in stands of low-volume black spruce and in areas where fire is important in maintaining browse for some kinds of wildlife.

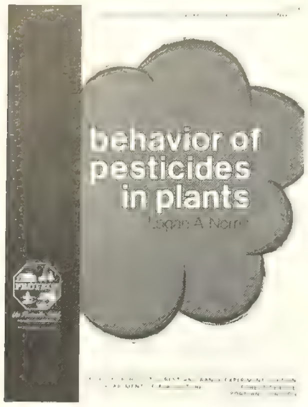
The BLM reports an average of more than 400 fires a year, with about 800,000 acres burned annually. Some years that total runs as high as 5 million acres. Although about two-thirds of the fires are man-caused, lightning fires do more extensive damage because they often start in inaccessible places.

In this environment, fire research is especially important. The Forest Service is currently reviewing its fire research program at the Institute of Northern Forestry at Fairbanks. The Institute is a field unit of the PNW Station. Since 1971, the research has concentrated on fire effects, emphasizing the ecological role of fire in the environment, and learning more about how fire affects succession in various forest types. Resource managers from the BLM and other groups are using this information.

What scientists have learned about fire in the northern environment is impressive. Their reports detail the role of fire in creating a vegetation mosaic that is unique to

chemicals in the environment

general


behavior of pesticides in plants

Logan A. Norris

PROTECT

Behavior of Pesticides in Plants, by Logan A. Norris (52)

The behavior of a pesticide determines its fate in all parts of the environment including plants. Pesticides in plants may be absorbed, stored, metabolized, and/or released to the environment. These processes determine both the pesticide's impact on the plant and its residue characteristics.

The behavior of a chemical results from the interaction between the properties of the compound and the environment. The environment has many components, and a chemical may interact with any or all of them. The chemical behavior we observe in the field is a result of many single interactions.

Scientists can accurately measure both the chemical properties and the environmental factors which interact to produce behavior. The results of some simple interactions can be predicted. However, the field of chemodynamics has not yet attained the sophistication necessary to quantify the multiple interactions which may occur between chemicals and their environment.

It will be difficult to develop a single predictive equation which includes the important primary and secondary interactions which produce chemical behavior, but such an equation is needed. A better understanding of the behavior of chemicals in organisms would result in greater pesticide effectiveness and fewer hazards in use. Pesticides will remain available to man only if he can learn to use them with greatest effectiveness on target organisms and minimum impact on the remainder of the environment.

The Entry and Fate of Forest Chemicals in Streams, by Logan A. Norris and Duane G. Moore (53)

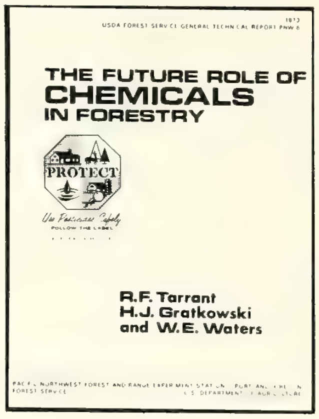
An interesting discussion of the distribution and fate of herbicides, insecticides, and fertilizer applied from the air to forest environments. Research findings and a long history of use indicate that most forest chemicals have minimum potential for pollution of the aquatic environment when they are properly used.

The authors discuss the distribution of aerially applied pesticides, including spray drift and atmospheric dispersion, dispersion in forest vegetation and soil, and the movement of pesticides to streams. The impact of fertilization and the behavior of various chemicals in the aquatic environment are also covered.

This is a general discussion, but specific enough to be highly informative. The paper was given at a symposium on Forest Land Uses and Stream Environment, in October 1970. Copies of the complete proceedings can be purchased for $6.25 each from Forestry Extension, Oregon State University, Corvallis, Oregon 97331, or by writing Continuing Education Publications, Waldo 100, Corvallis, Oregon 97331.

Pesticide Residue Dynamics in a Forest Ecosystem: A Compartment Model, by Warren L. Webb, Henry J. Schroeder, Jr., and Logan A. Norris (54)

This paper presents a computer model of the movement of pesticide residues, especially herbicides. This is important in determining the potential direct effects on target and nontarget organisms. The very long-term consequences of restructuring the vegetation in an ecosystem are not discussed. Simulations using the model trace the movement of two herbicides (2,4,5-T and picloram) through two different environments, one typical of an Oregon forest and the other typical of southern California chaparral. The model is written in DYNAMO.


THE FUTURE ROLE OF
CHEMICALS
IN FORESTRY

PROTECT

R.F. Tarrant
H.J. Gratkowski
and W.E. Waters

The Future Role of Chemicals in Forestry, by R.F. Tarrant, H.J. Gratkowski, and W.E. Waters (57)

Chemicals are useful, necessary tools for helping to meet needs for food, wood fiber, and water, while man readjusts his numbers and modes of life to the rapidly dwindling resources of the earth. The more selective, less persistent chemicals will continue to play an important role in forest resource management, probably for several decades. However, chemical use must eventually be minimized, for it is simply a system of treating symptoms of unhealthy ecological conditions created by nature or man in the past.

Technological, environmental, and socio-economic factors will add new dimensions to chemical use, placing greater demands on the research and development process.

Our pressing need, aside from solutions to problems of population pressures and extravagance in natural resource use, is rapid development of the ecological knowledge necessary to manage and maintain a healthy biosphere with minimum use of chemical tools.

Pesticides and Their Safe Use

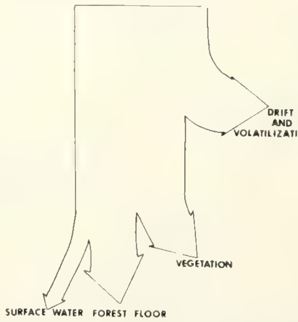
In 1971, a short course for pesticide applicators was conducted by OSU, the U.S. Forest Service, and the Division of Continuing Education. Two reprints from that session are available from the Experiment Station. They are:

The Behavior of Chemicals in the Forest, by Logan Norris (55), and

Principles of Monitoring, by Duane G. Moore (56).

Proceedings of the entire short course are still available. Cost for the proceedings is $6.50 plus postage (prepaid or included in the billing). *Pesticide Short Course* may be ordered from:

Continuing Education Publications
1633 Southwest Park Avenue
P.O. Box 1491
Portland, Oregon 97207



The initial distribution of aerially applied chemicals.

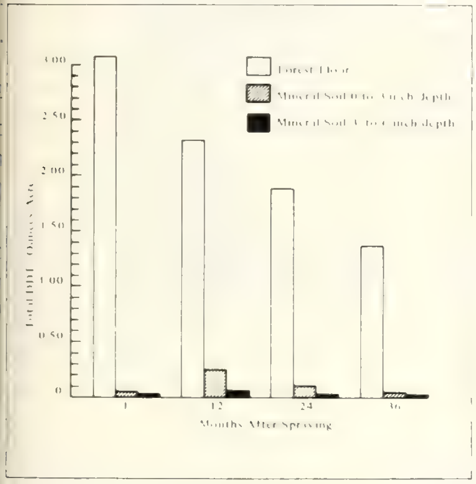
nsecticides; DDT nd others

DT Residues in Forest Floor and Soil After Spraying, Oregon—1965-68, by R.F. Tarrant, D.G. Moore, W.B. Bollen, and B.R. Loper (58)

report on the persistence of DDT in for- st soils after aerial spraying in eastern Ore- on. One month after the application of DT at the rate of 12 ounces per acre, 3 unces were found in the forest floor. Three ears later, the DDT content had decreased y more than 50 percent, and had not eached into the surface mineral soil.

Vhat little DDT got into streams rapidly lecreased to undetectable levels. No effect of he spray was noted on soil microbial popu- ations, nitrification rate, or amount of itrate nitrogen in the soil.

bout 26 percent of the DDT spray eached the ground initially. Through the ction of litterfall, eventually one-third of he chemical got to the forest floor. The eed for more efficient aerial methods of hemical application is evident.



Total DDT in forest floor and mineral soil during 36 months after aerial spraying, Oregon 1965-68.

DDT Residue Accumulation and Decline in Kidney Fat of Lambs Grazing Sprayed Forest Range, by Gerald S. Strickler (59)

DDT residues in fat of young lambs grazing in forest sprayed with DDT for Douglas-fir tussock moth control increased rapidly up to 2 weeks, then decreased. Following removal of lambs to unsprayed feed for 14 to 22 weeks, fat residue levels declined, but only those in the shortest treatments (1 and 2 weeks of grazing) fell significantly below the 5-p/m tolerance level.

DDT, Bluebirds and House Wrens

In an eastern Oregon study, there was no harmful effect on mountain bluebirds and house wrens when DDT was sprayed at the rate of 3/4 lb. per acre to control the Douglas-fir tussock moth. Scientists compared the number of eggs laid, eggs hatched, and nestling mortality for both sprayed and unsprayed plots. Most nests were in nest boxes which had been put up to attract birds for the study.

For details, see *Effects of Aerial Application of DDT for Tussock Moth Control on Nestling Survival of Mountain Bluebirds and House Wrens,* by Jack Ward Thomas and D. Calvin McCluskey (60).

Jack Thomas examining nest box

Effect of Zectran on Microbial Activity in a Forest Soil, by W.B. Bollen, K.C. Lu, and R.F. Tarrant (61)

When Zectran or No. 2 fuel oil was applied to soil in concentrations far greater than those that could result from current operational application rates, neither material adversely affected soil microbial activity. We conclude from these data that low-volume applications of Zectran as an insecticide for forest use poses no hazard to soil microbes.

the far north and beneficial to the wildlife and plant communities involved. In short, it is distinctly a "fire environment," in which the plants and animals that live there have adapted to the periodic burning of the forests.

There are several vegetation types in the interior. All are susceptible to fire, but each reacts somewhat differently. Biologist Joan Foote of the Institute of Northern Forestry has been conducting studies to learn more about those responses. She has been at the laboratory since 1964, and in 1971 began work on fire effects. A map in her office shows all the fires in northern Alaska in the past 10 years. Her goal is to study fires in order to pin down the successional patterns that have occurred in each of the various forest types.

So far, 130 burned stands have been studied. Most of the research plots are within 60 miles of Fairbanks (it makes travel easier). Plots have been set up at all of the areas that can be reached by road. Many plots, however, must be visited by helicopter, float plane, or boat.

Black spruce grows primarily on the poorer sites, in cooler places that may be boggy and are usually underlain by permafrost. It is the spindly black spruce forests for which the taiga is named. Taiga is a Russian word meaning "land of little sticks."

In the black spruce forest, six separate community types have been identified. In the white spruce community, four types have been identified.

In a typical black spruce type, the mature forest might be about 50 years old, and the trees 2 to 5 inches in diameter. In boggy areas, trees grow on sphagnum moss, sometimes underlain by peat that is over 25 feet deep. On better-drained sites, feathermosses are more typical and cover the ground in layers about 12 inches thick. There are also a few herbs and shrubs.

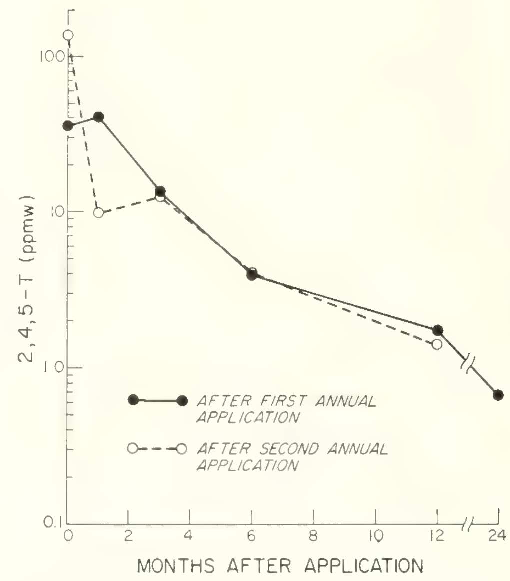
When the forest burns, there is very little left. The trees are dead, the moss is blackened, and the shrubs are killed. Gradually, the shrubs begin to regrow from the roots and rhizomes. Aspen regrow from root suckers, and birch from stem suckers. At the end of a year, some very small black spruce seedlings appear. The hotter the fire, the longer it takes for the green to come back. Within 5 years, trees may be 3 inches to 2 feet tall, the shrubs are coming back, and the willow trees are taller than a man's head. Blueberry shrubs have regrown and are producing berries again.

use of herbicides
general

Behavior and Impact of Some Herbicides in the Forest, by Logan A. Norris (62)

Foresters are making management decisions about the use of herbicides to accomplish a variety of management purposes. Sound decisions require a good understanding of the concepts involved, as well as an adequate data base. This paper considers the environmental consequences of herbicide use in the terrestrial part of the forest environment. It provides foresters with concepts and a partial data base for assessing the hazards associated with the use of four herbicides: 2,4-D, 2,4,5-T, amitrole and picloram.

The paper is based on a talk reprinted from *Herbicides in Forestry,* 1975 Proceedings of John S. Wright Forestry Conference, Purdue University, West Lafayette, Indiana.

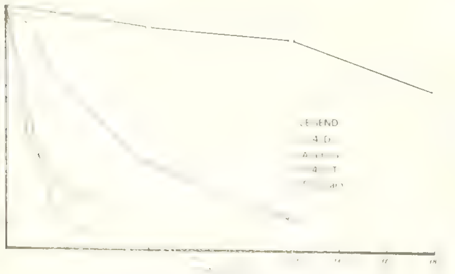


Residues of herbicide in forest floor after two annual applications of 2,4,5-T at 2 lbs./acre by helicopter in April.

Degradation of Herbicides in the Forest Floor, by Logan A. Norris (63)

The herbicides 2,4-D, 2,4,5-T, amitrole, and picloram are degraded in forest litter but at markedly different rates. The degradation of 2,4-D differs slightly in litter from different vegetation types, but these differences are not important in the field. 2,4-D is degraded rather rapidly, but 2,4,5-T is somewhat more persistent—about 90 percent will be gone after 4 months. Picloram is considerably more resistant to degradation than the other herbicides studied, but it is biodegradable. Amitrole is rapidly degraded.

Various constituents of spray formulations may retard the degradation of 2,4-D but the addition of picloram, 2,4,5-T, and diesel oil do not. Scientists have also found that some chemicals can be applied in the forest a month prior to spraying of herbicide with no effect on degradation of 2,4-D. These chemicals include DDT, phosphamidon, or carbaryl. However, degradation of 2,4-D is stimulated when 2,4-D and DDT are applied together.



Recovery of 2,4-D, 2,4,5-T, amitrole, and picloram from red ald[illegible]

Chemical Brush Control and Herbicide Residues in the Forest Environment, by L.A. Norris (64)

This paper reports research from a 5-year U.S. Public Health Service grant to determine the dangers associated with the use of herbicides in the forest. Data on stream pollution are emphasized.

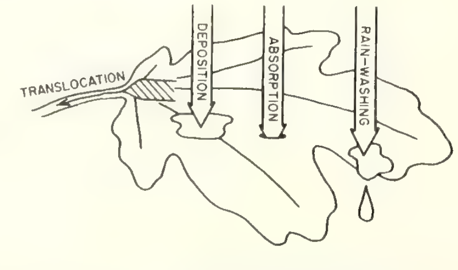
The land manager concerned with the planning and use of herbicides should remember the three most important things learned from these research efforts:

1. The direct application of herbicide to the water surface is the most important cause of stream contamination.

2. Avoid treating areas with a high water table.

3. When operating in areas which are particularly sensitive from a biological or public relations standpoint, stream contamination can be held to an absolute minimum by recognizing and avoiding those situations which lead to direct application to streams or surface water.

4. Herbicides can be used safely in the forest in most instances.



The fate of chemicals intercepted by foliage.

Chemical Brush Control: Assessing the Hazard, by Logan A. Norris (65)

An adequate evaluation of the hazard associated with the use of any chemical agent requires consideration of both the toxicity of the material and the potential for exposure of non-target organisms. The hazard can be high only if both the toxicity of the chemical and the potential for exposure to a significant dose are high.

This paper includes specific data on toxicology and organism exposure for four herbicides. These data can be used to evaluate the hazards.

The relatively large doses of 2,4-D, amitrole, 2,4,5-T, and picloram required to produce acutely toxic responses in most nontarget organisms are not likely to occur from normal chemical brush control operations on forest lands. The short persistence, lack of biomagnification in food chains, and the rapid excretion of these herbicides by animals preclude chronic exposure and, therefore, chronic toxicity. A long history of field use and research shows our common brush control chemicals can be used with minimum hazard to the quality of our environment.

Logan Norris

Field Application of Herbicides—Avoiding Danger to Fish, by Erland T. Juntunen and Logan A. Norris (66)

Chemical weed and brush control with herbicides is an important land management practice in modern agriculture and forestry. In some cases, herbicides are applied directly to bodies of water for aquatic weed control. More commonly, herbicides are applied to lands adjacent to waterways for general weed and brush control.

The responsible applicator will avoid damage to fishery resources by being fully aware of a particular herbicide's potential hazard to fish. Herbicide applications should be considered hazardous to fish when there is the probability fish will be exposed to herbicide concentrations which are harmful. This bulletin groups commercial herbicide formulations by toxicity to aid in selecting the particular formulation of least hazard to fish.

2, 4-D; 2, 4,5-T; and others

A Preliminary Evaluation of the Hazards of 2,4,5-T in the Forest Environment, by Marvin L. Montgomery and Logan A. Norris (67)

Increasing concern about the quality of man's environment has resulted in careful scrutiny of the use of 2,4,5-T for vegetation management. Aerial applications of 2,4,5-T to forest lands result in an initial low-level, short-term stream contamination which does not represent a significant hazard to fish or animals. The extensive adsorption and degradation of 2,4,5-T in the forest floor prevent subsequent movement from treated areas to surface and ground waters. The primary exposure of animals to 2,4,5-T will be by ingestion of treated vegetation. Rainfall, growth dilution, and degradation markedly reduce herbicide residues in vegetation within a few weeks after application.

Effects on Wildlife

The effects of the herbicides 2,4-D and 2,4,5-T on the forest environment have been extensively studied. Conclusions from three papers are included here:

Toxicity of Various Formulations of 2,4-D to Salmonids in Southeast Alaska, by William R. Meehan, Logan A. Norris, and Howard S. Sears (68)

A very technical study that reports results of laboratory tests to determine the toxicity of 2,4-D to young salmon, Dolly Varden char, and rainbow trout in southeast Alaska. Various doses of several different commercial grades of 2,4-D were tested.

Objectives of the study were to compare the toxicity to juvenile salmonids of various formulations of 2,4-D and to compare the toxicity of a given chemical under identical laboratory conditions to the same species of fish (coho salmon) in Oregon and in Alaska. The latter objective was to evaluate extrapolation of results over a wide geographic range. The isooctyl ester of 2,4-D was the least toxic of the esters tested. Oregon and Alaska coho salmon responded the same to various concentrations of the chemical.

The Kinetics of Adsorption and Desorption of 2,4-D and 2,4,5-T, Picloram, and Amitrole on Forest Floor Material, by Logan A. Norris (69)

A very technical paper that discusses the interaction of herbicides with material on the forest floor. Results indicate that the speed and degree of adsorption of 2,4-D, 2,4,5-T, picloram, and amitrole on forest floor material varies with the herbicide.

Short-Term Effects of 2,4-D on Aquatic Organisms in the Nakwasina River Watershed, Southeastern Alaska, by Howard S. Sears and William R. Meehan (70)

Approximately 400 acres of cutover land on the Nakwasina River watershed in southeastern Alaska were treated with 2,4-D to inhibit the growth of broad-leaved plants. No immediate mortality to salmonid fishes or aquatic invertebrates was attributable to the spray. Samples of water and fish had concentrations of 2,4-D well below the level generally considered to be lethal to aquatic organisms. The results were considered inconclusive because of the lack of information on the pretreatment condition of the test animals. Further research is required to assess the immediate and long-term effects of these spray operations in Alaska.

A Discussion on Herbicides, by Luke Popovich, Michael Newton, and Logan A. Norris, and

Statement on 2,4,5-T and TCDD, by Frank Dost, James Witt, Michael Newton, and Logan A. Norris (71)

The July 1975 issue of the *Journal of Forestry* carries an excellent discussion and summary of the use of herbicides, especially with regard to 2,4,5-T and its toxic contaminant TCDD or dioxin. A panel of experts is consulted. The following discussion is of special interest:

No human health problems or effects on other animals of any sort had been associated with widespread uses of 2,4,5-T over a 22-year period in American forests. However, in 1969, a research laboratory which was developing a very sensitive test method for cancer and birth defects found a significant induction of fetal deformities by 2,4,5-T under these special test methods.

Examination of the 2,4,5-T used in the tests revealed an impurity called dioxin or TCDD present at the unusually high level of 27 parts per million. It was determined over the course of many more studies that it was this impurity which caused these deformities, not the 2,4,5-T. TCDD is formed as a by-product of one of the steps in the manufacture of 2,4,5-T.

In recent years, improved manufacturing processes have reduced levels of TCDD in the herbicide. The experts consulted here conclude that the registered uses of 2,4,5-T in the forest do not constitute an unacceptable hazard to humans, animals, or the general quality of the environment.

Other highly technical articles that discuss the possible cancer producing hazards of 2,4,5-T and its contaminant TCDD are included in the bibliography under (72).

Eventually the burned spruce forest is replaced. Along the way, many species appear which provide good habitat for wildlife. For example, most of the large populations of moose in Alaska can be traced to a large fire or series of fires in the past that have increased the supply of shrubs, willows and other hardwoods. Snowshoe rabbits also love the willow. They nibble the lower branches, leaving the upper branches to the moose.

Beneath the surface other things are going on. Much of the taiga is underlain by permafrost. Around Fairbanks, about 50 to 75 percent of the area is permafrost. The frozen soil extends from a foot or so beneath the surface down to 400 to 500 feet or more. Fire has a profound effect on the permafrost layer. The removal of the understory and the forest canopy allows sunlight to reach and warm the soil.

Ecologist Les Viereck of the Institute of Northern Forestry is an expert on both tundra and taiga vegetation, and has studied the effects of fire on the taiga environment. "Following fire," he says, "surface temperatures go up, warming the underlying permafrost, and causing melt. Thawing continues at a high level for 15 to 20 years. After about 25 to 30 years, the thawing rate recedes to where it was before the fire." Ecological information such as this is needed to develop policies for the management and protection of these northern forests from fire. It is important to know when and where fires should be controlled and where they should be left to go out naturally.

In developing a new program of fire research in the interior, researchers are also looking at the need for fire control studies. The environment is significantly different from other forest environments in the United States. Special techniques may be needed to manage the taiga.

It is very important to develop a fire management policy for the interior, one that will recognize the very special nature of the taiga ecosystem. If the natural mosaic of vegetation is to be maintained, then some fires must be allowed to burn. Otherwise, the tendency will be to move toward a climax spruce forest everywhere.

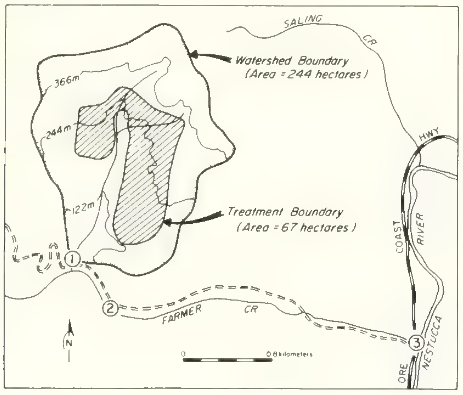
A fire management policy is also needed for maintaining caribou habitat. It is generally agreed that fire destroys the lichen-rich winter range of the caribou. Some have estimated that it may take as long as 100 years for the range to return to its pre-burn condition.

end of "insights"

Dicamba Residues in Streams After Forest Spraying, by Logan A. Norris and Marvin L. Montgomery (73)

Concern about the possible hazards of the herbicide 2,4,5-T has led to study of possible alternative chemicals for brush control. Dicamba, an auxin-type herbicide, is one possibility. It is both soil and foliage active and has a relatively low toxicity.

This paper reports results of a study to learn more about its residues in streams. From their observations, the researchers conclude that dicamba can be used for brush control on forest lands with little or no impact on aquatic environments—if direct application to surface waters is minimized by using appropriate spray application techniques. Residues posed no acute hazard to aquatic organisms or to downstream water users. The short persistence of the herbicide in water precludes chronic exposure.


SALING CR
Watershed Boundary (Area = 244 hectares)
366m
244m
122m
HWY
Treatment Boundary (Area = 67 hectares)
COAST RIVER
1
2
3
FARMER CR
NESTUCCA
ORE
N
0
0.8 kilometers

Farmer Creek tributary watershed, treatment area, and sampling points one, two, and three.

rodenticides

Influence of Endrin on Soil Microbial Populations and Their Activity, by W.B. Bollen and C.M. Tu (79)

Endrin applied to soil at rates of more than three times the maximum that might be expected from application of endrin-treated tree seed exerted no appreciable effect on numbers of soil microbes or on ammonification, nitrification, or sulfur oxidation. The decomposition of soil organic matter, as indicated by the production of CO_2, was increased significantly in the presence of endrin.

Results of our study agree substantially with other studies, indicating that a very high rate of endrin in soil would be necessary to alter microbial properties. We conclude that the relatively insignificant amount of endrin formulation applied to forest soil from coated tree seed is unlikely to damage soil microbes and their activities.

Arasan in Endrin Treatments to Protect Douglas-fir Seed From Deer Mice, by G.L. Crouch and M.A. Radwan (80)

The use of arasan, along with endrin, to protect forest tree seeds from rodents is not a good idea. The compound did not lower seed consumption when used alone. In addition, the chemical also caused significant reductions in seed germination.

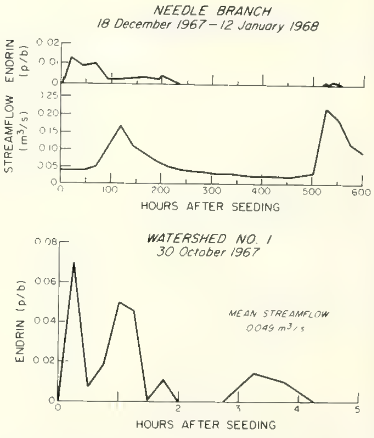
Endrin in Streams

Endrin, a chlorinated hydrocarbon insecticide, has been extensively used in the Pacific Northwest for many years to protect directly sown Douglas-fir seed from seed-eating rodents. The amount of endrin thus introduced into the forest environment is exceedingly small. However, endrin-treated seed may enter small streams flowing through seeded areas. Since endrin is one of the most toxic pesticides to fish, there is concern about the potential hazard.

In this study, scientists sought to determine how much endrin might get in streams and how persistent it might be. Detectable residues were found in a stream with steep gradient for no more than 5 hours after seeding. In a slower flowing stream, endrin could be detected for 11 days. Endrin was again detected in the low gradient stream during the high flow of a winter storm 23 days after seeding. Maximum concentrations, however, were well below the 96-hour median tolerance limits for important fish species.

The report is *Endrin in Forest Streams After Aerial Seeding With Endrin-Coated Douglas-fir Seed,* by Duane G. Moore, James D. Hall, and Wayne L. Hug (81).

Other highly technical publications are listed in the bibliography under (82). One deals with the systemic properties of tetramine, an extremely toxic chemical once considered for use as a seed protectant in reforestation. The other report is on the effects of organotin compounds on microbial activity in the soil. Organotin compounds have fungicidal, batericidal, and rodent repellent properties as well as potential for use in insect control.



Concentration of endrin in streamflow after aerial seeding with endrin-coated Douglas-fir seed: Needle Branch Watershed—seed treated with 1.0 percent endrin and sown at 0.84 kilograms per hectare; Watershed No. 1—seed treated at 0.5 percent endrin and sown at 0.56 kilograms per hectare.

A few other, rather highly specialized reports are included in the bibliography for this section (83).

arsenic compounds

Studies of the Safety of Organic Arsenical Herbicides as Precommercial Thinning Agents: A Progress Report, by Logan A. Norris (74)

In early 1970, the Forest Service invited interested scientists and forest land managers in the Pacific Northwest to meet to determine gaps in knowledge about the hazards associated with forest use of the organic arsenical herbicides, MSMA and cacodylic acid. As a result of these meetings, a cooperative effort coordinated by the PNW Station was initiated to determine the behavior and impact of organic arsenical herbicides in the forest. Specifically, these studies are to:

1. Measure the initial distribution of organic arsenical herbicides among components of the forest environment.

2. Determine their persistence, movement, and fate in the forest.

3. Characterize the acute and chronic toxicity of these chemicals to large and small animals.

Results of these studies will be used to determine the degree of risk involved in current chemical thinning practices and to make recommendations which will minimize the risk of future practices. This report covers the research approach of each cooperative study and summarizes and interprets results to date.

Other reports in this section describe results of the study of the effect of arsenic compounds on forest workers (75), rabbits (76), cattle (77), and soils (78).

So far, the conclusion seems to be that arsenic compounds are fairly safe, when applied correctly and with appropriate safety precautions. Forest workers using silvicides for thinning projects do absorb arsenic into the skin or in other ways. But the chemical appears to be excreted in a short time and there is no evidence that arsenic levels continue to increase. Workers, and their supervisors, should exercise proper safety precautions.

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timber quality and utilization

See also:
Economics
Mensuration
Resource Evaluation
Silviculture
Insect and Disease
Alaska
Gadgets

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wood utilization

Status of Timber Utilization on the Pacific Coast, by John B. Grantham (1)

A 42-page report outlining the opportunities to improve timber utilization by reducing logging residue in the Pacific Coast region. There, some 14 million tons of residue accumulate each year and some 3 million tons of unused bark create a disposal problem at the mill.

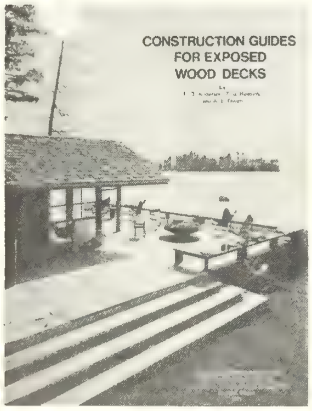
Grantham discusses: (a) the quantities and characteristics of wood residue available, (b) wood residue use now, (c) progress that is being made toward more complete utilization, and (d) administrative changes for fuller timber utilization.

Utilization Estimates for Western Softwoods—Trees, Logs, and Residue, by Donald R. Gedney and John W. Henley (2)

How much of the wood fiber in trees is actually used and becomes part of an end product? Answers to that question were published in 1971 and based on then-recent information on wood utilization.

At that time, wood utilization looked like this:

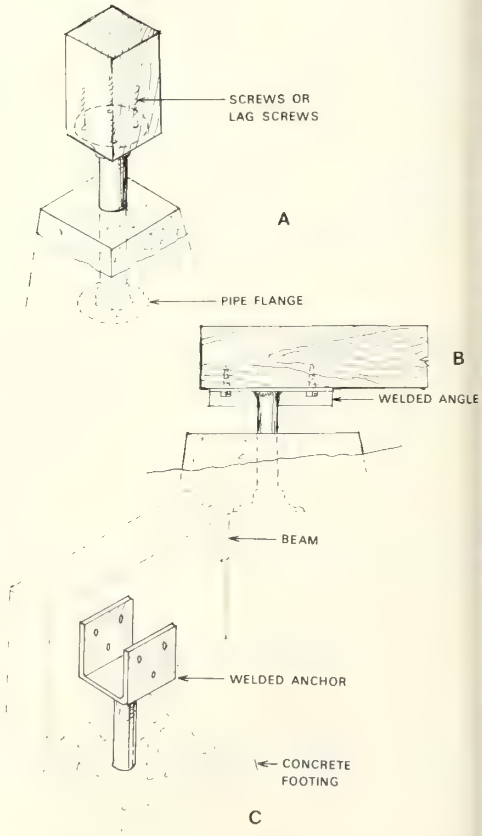
1. Of the tree harvested, 85-95 percent of the total cubic foot content reached a processing plant.
2. Of the log processed, 44-50 percent is used for primary products.
3. Of the mill residue generated, 81 percent is used.
4. Of the total sound volume of the tree, 76-86 percent of the cubic foot content is used.


CONSTRUCTION GUIDES FOR EXPOSED WOOD DECKS

Construction Guides for Exposed Wood Decks, by L.O. Anderson, T.B. Heebink, and A.E. Oviatt (3)

The all-time "best seller" publication from this Experiment Station gives guides for the design, finishing, and treatment of outdoor wood decks. Both good and poor construction details are illustrated for the benefit of architects, builders, and homeowners.

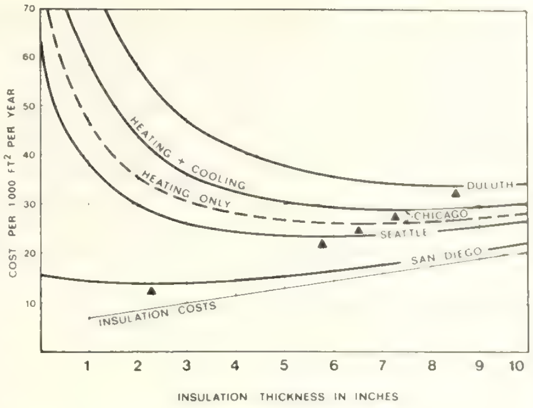
Copies are no longer available from the Experiment Station, but may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Order as Agriculture Handbook 432, stock number 0100-2577. The last time we checked the price was $.75.



Pipe and flange anchor. A-pipe flange; B-welded angle (low decks); C-saddle anchor for low decks.

)ptimum Insulation Thickness in Wood-Framed Homes, by A.E. Oviatt (4)

Vew design methods must be developed to educe energy waste in buildings. This tudy examines an economic approach to he design of thermal insulation in the home ınd demonstrates graphically that an optinum point of insulation thickness occurs vhere total costs of insulation and energy ›ver the useful life of a building are a mininum. The optimum thickness thus deternined exceeds that recommended by older lesign criteria and significantly reduces ›nergy requirements for heating and cooling.



Optimum roof-ceiling insulation thickness.

Aoisture Content of Glulam Timbers in Use in the Pacific Northwest, by Alfred E. Oviatt, Jr. (5)

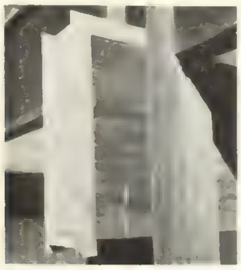
'reliminary results of this study in western Vashington and Oregon generally confirm :urrent industry standards and recommenlations for the design of glulam structural nembers. However, indications are that :xisting classifications of exposure do not ully cover all possible use conditions, and hat the application of present standards frequently must depend on engineering judgnents in areas where field data are lacking.

The Influence of Design on Exposed Wood in Buildings of the Puget Sound Area, by Edward W. Schein (6)

This report summarized a field survey of the ›erformance of exposed structural wood nembers.

The study included a survey of 175 buildıngs in the Puget Sound area of the State of Washington. Building designers, owners, and custodians were consulted for details of construction and maintenance. Though the primary concern was with contemporary structures, the influence of design was also observed in some older examples. Twenty-seven representative buildings were selected for analysis from the original survey list, and sketches of these are contained in an appendix. Illustrations accompanying the text are keyed to these by suffix number.

The objective of the study was to identify the best existing design solutions to exposure hazards.

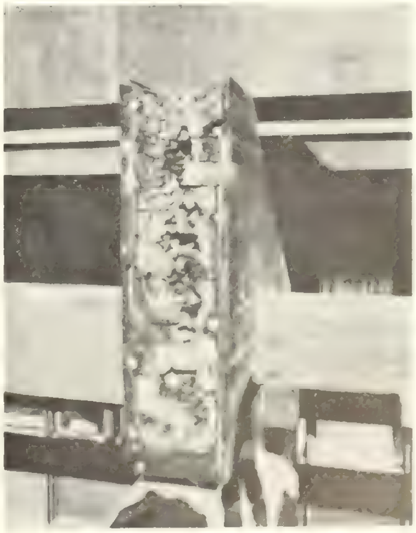


A good metal flashing cap design. This cap channels water runoff away from the sides of the beam.

Protecting Exposed Ends of Timber Beams in the Puget Sound Area, by A.E. Oviatt (7)

When heavy timber members are fully exposed to the weather, changes in moisture content caused by the action of sun and rain are appreciable. This exposure is most severe on end-grain surfaces which absorb moisture rapidly. Stresses in beams of large sections usually cause checking, staining, and degradation of finishes. In the rainy climate of the Puget Sound area, moisture contents in the wood readily reach levels at which decay occurs, and even pressure-treated timbers may decay if deep checks allow water to penetrate to untreated material in the interior.

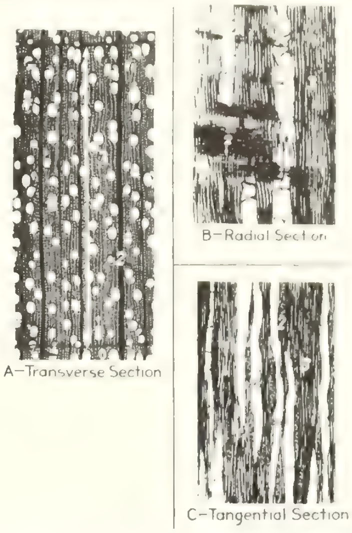
Finishes, flashing, and protective covers may be used to reduce these effects; and experimental evaluations of many potential protective methods are needed to identify systems which provide satisfactory durability and minimize maintenance. This report describes weather exposure tests of 12 protective methods, with observations of moisture content and appearance over a 3-year period. One finishing system and two types of protective covers appear to provide adequate protection.



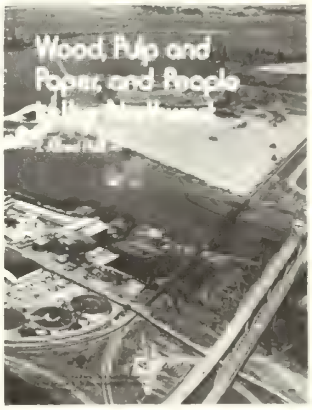
Decay in an exposed beam end

Utilization of Bigleaf Maple of the Pacific Northwest, by Herman M. Johnson (8)

A rather old (1932) report but a fascinating (and still available) discussion of the importance of bigleaf maple—its range, annual production and consumption, wood properties, and utilization.



Highly magnified sections of bigleaf maple showing structure.



Wood, Pulp and Paper, and People in the Northwest, by J. Alfred Hall (9)

A fascinating discussion and explanation by a former Station Director of what goes on in the pulp and paper industry, with emphasis on environmental issues, natural resources use, economic history in the Northwest, and pulp and papermaking technology. Designed for use by high school students.

American Wood Series

The Department of Agriculture publishes a series of papers on *American Woods* that give general information on distribution of the species, their growth characteristics, wood properties, and wood uses. Several (10) were written by Experiment Station scientists and are currently available:

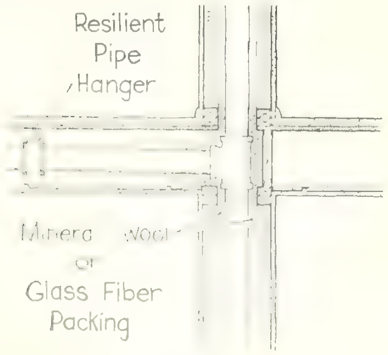
Red Alder, American Woods FS-215, 1971
Alaska-Cedar, American Woods FS-224, 1971
Sitka Spruce, FS-265, 1973
Port-Orford-Cedar, FS-228, 1973.

sound control

Insuring Noise Control in Wood-Framed Buildings, by J.B. Grantham and T.B. Heebink (11)

Lab test values of the sound insulation provided by several wood-framed wall and floor constructions illustrate that one can design for any required resistance to noise transmission between living units. However, designers and builders must follow practices that insure the expected performance when a wall or floor is incorporated in a building. Practices that reduce the expected sound insulating properties of a wall or floor are described and illustrated from field test experience. Losses due to flanking may reduce the sound transmission class (STC) of a wall by 10 points (to half its predicted effectiveness), but the combination of leaks and flanking generally reduces the STC by only 1 to 5 points.

Articles in this category are quite technical and of interest primarily to builders or architects. For a list of publications, see (12) in the bibliography for this section. Another good source of information on this subject is the Western Wood Products Assoc., Yeon Building, Portland, Oregon 97204.



One means of isolating plumbing lines to control air-borne and structure borne noise.

product yield potential

Background

In 1970, former PNW Station Director Philip A. Briegleb commented on the estimation of timber quality and the appraisal of timber values. Briegleb said, "Public agencies and the forest industry are much concerned with how timber is appraised for sale. An important and difficult part of the appraisal job is estimating the quality of a tract of timber in terms of the amount of the various grades of lumber or other products that can be produced from it."

The Forest Service in cooperation with other public agencies and the forest industry is conducting research to develop better methods for estimating the potential lumber and veneer grade yield from standing timber (13).

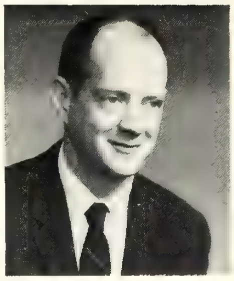
The work performed by PNW scientists in timber quality research is extensive. Basically this research can be divided into studies dealing with the product yield potential of the total resource, methods for estimating the timber quality of various species, and related studies in the field of forest products utilization.

At the present time there are about 30 current publications which deal with these subjects. Some of these are listed in the bibliography for this section.

Standing Dead Timber

What are we going to do with all that dead timber? Questions such as this, referring to the more than 5 billion board feet of dead timber in the West, have accelerated research on the product potential of standing dead timber. When studies are completed, new information will be available for standing dead white pine and for true firs killed by the Douglas-fir tussock moth in eastern Oregon. Results to date show that 2 years after mortality, tussock-moth-killed true fir retained 73 percent of the value of the live tree. Standing white pine in Idaho retained 72 percent of its value 2 years after death. In these studies, a close relationship has been observed between the length of time the timber has been dead and its recovery value.

Preliminary information is available in a paper presented at the 1976 Rocky Mountain Forest Industries Conference. See *Potentials from Salvage Timber,* by Richard O. Woodfin, Jr. (14).



Tom Fahey

Product Yield

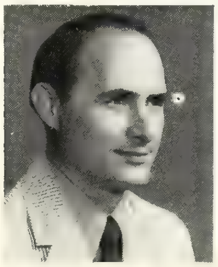
Information about product yield potential includes studies for Douglas-fir lumber and veneer recovery (15), true fir lumber and veneer recovery (16), and other species such as old-growth coast Douglas-fir (17), and Black Hills ponderosa pine (18).

Resource and plant managers concerned with estimating timber quality and the product yield of standing timber at the mill site can benefit from the extensive research conducted by PNW scientists. Generally, these studies pinpoint product grade yield, lumber or wood product loss, and cubic recovery relationships. They also report on lumber and wood product cubic recovery.

Improved utilization to reduce degrading, or the loss of lumber in volume and value due to treatment processes, can play a critical role in the economics of a mill operation. It is important to identify the manner and the place in processing at which wood loss occurs. And researchers are concentrating on this problem. For example, in his paper, *Wood Loss in Plywood Production—Four Species* (19), Richard O. Woodfin says that the best point to observe loss in a veneer mill is beyond the clipper, after the veneer has passed the crew or the equipment that pulls the veneer onto carts.

In this paper, Woodfin explores the relationship of dry-end wood loss in coast Douglas-fir, red and white fir, western hemlock and Black Hills ponderosa pine. He provides valuable information which can help the mill manager estimate wood loss and veneer recovery for these species.

The Woodfin paper is just one example of a growing volume of information in the area of product yields and losses. Other studies dealing with degrading include white fir wood properties (20), the distribution of lumber degrade in white fir trees (21), veneer losses in red and white fir (22), and changes in lumber grade during drying (23).



Dick Woodfin

Conversion Factors for the Pacific Northwest Forest Industry: Converting Forest Growth to Forest Products, by David A. Hartman and others (24)

This is a revised and expanded successor to he classic *Conversion Factors for Pacific Northwest Forest Products.* It is an entirely new handbook and reference manual that will meet the demands of many in the forest ndustry for a quick, convenient one-stop source of conversion and recovery factors.

t features a completely integrated system of conversion and recovery factors currently used in the Pacific Northwest to measure standing timber, logs, poles and piling, cord and pulpwood, lumber, veneer and plywood, pulp and paper, composition board, shake and shingles, and wood residues.

Up-to-date recovery factors have been included along with full metric conversions. There are special sections on wood residues as fuel, log scaling practices and correction factors, and wood weights and shrinkage. Other features are log and tree volume tables, common tables of equivalents (US and metric), forestry factors, and a glossary of terms and units.

The report—a handy 6x9-inch size with 124 pages, durable cover, and wire binding —can be obtained from the University of Washington, Institute of Forest Products, Seattle, Washington 98195, for $5.30.

Marlin Plank

Lumber Yields by the New Timber Cruising Log Grades for Old-Growth Coast Douglas-fir, by Marlin E. Plank and John W. Henley (29)

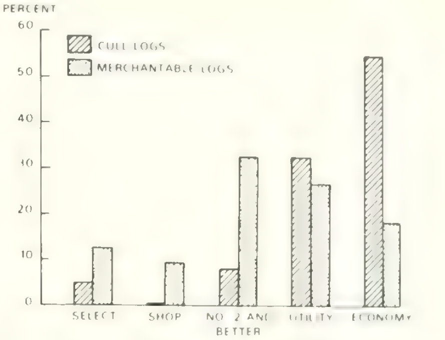
Lumber grade yield information is presented based on a new system of grading old-growth coast Douglas-fir. The report contains recovery on nearly 5,000 logs that were sawn in 10 sawmills in Washington, Oregon, and California.

The logs produced nearly 2.7 million board feet of lumber. About 54 percent of the lumber production was in 2-inch dimension, 10 percent was 1-inch boards, shop was about 12 percent, and other items thicker than 2 inches accounted for 24 percent of the total. Average lumber grade yields are shown in curve and table form.

On the average, about 64 percent of the gross cubic content of the log was manufactured into rough green lumber. About 25 percent of volume was lost as shrinkage and planer shavings, and about 50 percent of the cubic content of the log was shipped as lumber. These relationships are shown in tables and curve form.

Lumber Potential for Cull Logs in the Pacific Northwest, by Thomas A. Snellgrove and David R. Darr (31)

Cull log volume left after logging in western Washington and western Oregon amounts to less than 10 percent of the log volume consumed by the lumber industry in the two states. Even though about 47 percent of the gross cubic volume of cull logs could be manufactured into lumber, the lumber produced would be in low grades. This study indicates that the economic feasibility of using cull logs for lumber manufacture is marginal except when lumber prices are very high.



Average percent of lumber recovery by lumber grade.

Courtesy Fort Collins Coloradoan

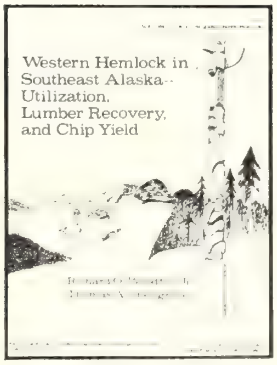
Tom Snellgrove

Lumber Recovery

The reverse side of the coin, the recovery of lumber and wood products, is equally well represented by studies such as *Predicting Product Recovery from Logs and Trees,* (25). This paper provides estimating equations, based on the size of logs and trees, that can be used to predict the amount of lumber, veneer, pulp, or other products that can be produced from trees.

In addition, specific area and species product yield reports are available for red and white fir in central California (26), western white pine in Idaho (27), second-growth Douglas-fir (15), and old-growth coast Douglas-fir (17) and highly defective, low grade coast Douglas-fir (28). Reports which focus on specific milling operations and lumber recovery are available for grand fir and Douglas-fir thinnings at bandmill and chipping canters (16).

Gene Pong


Western Hemlock in
Southeast Alaska--
Utilization,
Lumber Recovery,
and Chip Yield

Western Hemlock in Southeast Alaska—Utilization, Lumber Recovery, and Chip Yield, by Richard O. Woodfin, Jr., and Thomas A. Snellgrove (30)

This is the first published information on lumber recovery from western hemlock trees in southeast Alaska national forests. Logs for this study were sawn at a southeast Alaska mill that was cutting for the Japan export market.

The total of 1,261 sawn-length logs in the study produced about 335,400 board feet of lumber. Over 88 percent of this volume was in 4-inch-thick items, primarily nominal 4 by 4's. Lumber grade recovery was concentrated in two grades: Standard and Construction.

Sawing the 1,165 noncull logs (logs at least one-third sound by Scribner Scale) resulted in a 20-percent overrun from net scale. The cubic lumber recovery was 48 percent of the gross cubic log volume. In contrast, the 96 cull logs yielded only a 26-percent cubic recovery. Average scaled defect for the 1,165 sawn, noncull logs was 19.6 percent. Defect percentages were lowest for the peeler and No. 3 grade logs.

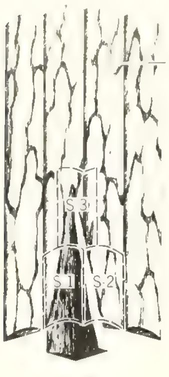
The amount of ovendry chippable wood is discussed and variation by log size illustrated. Examples explain practical application of this information.

Logging residue accounted for 23.3 percent of the total tree volume. Residue types recognized were broken logs, long butts, unused volume to an 8-inch top (includes cull logs left in the woods), and the volume between the used top and total height. These amounted to 3.2 percent, 5.7 percent, 3.6 percent, and 10.8 percent, respectively, of total tree volume.

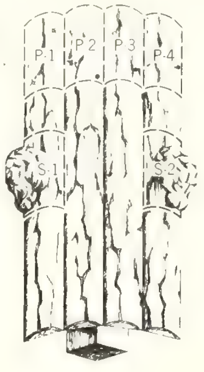
Log Grading

Resource managers and wood processors are constantly faced with the question of timber value. Two factors, log grades and defects, play a critical role in estimating value. Constant refinements in these systems of classification allow those concerned with estimating timber quality and price to make more reliable judgments about the resource.

At PNW, log grading, or timber quality estimating systems, have been developed or are available for old-growth and second-growth coast Douglas-fir (32), western white pine (33), ponderosa pine and sugar pine (34), and inland Douglas-fir (35). The *Pocket Guide to the Improved Grading System for Ponderosa Pine and Sugar Pine Saw Logs in Trees* (36) allows timber cruisers to independently grade each log by identification of both primary and secondary defects.



Grade 1



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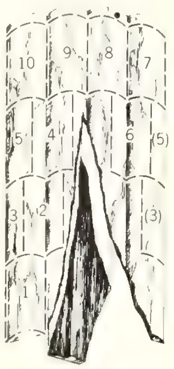

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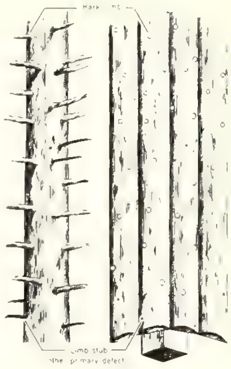

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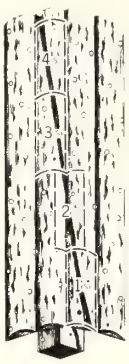
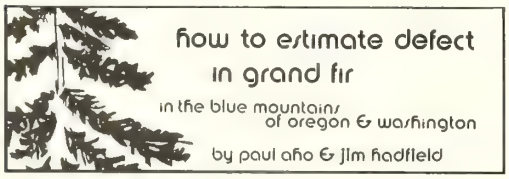


Grade 5

Defect Estimation

PNW scientists, conducting research on forest diseases, have made a strong effort to extend research results into working tools for resource managers. Research data has been compiled into "how to" brochures which can be taken to the field and used to reliably estimate a variety of defects. At the present time, three of these pocket-sized guides are available.

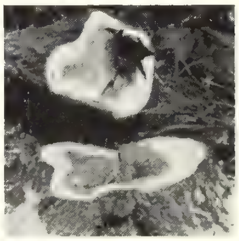


how to estimate defect
in grand fir
in the blue mountains
of oregon & washington
by paul aho & jim hadfield

1. *How to Estimate Defect in Grand Fir in the Blue Mountains of Oregon and Washington* (37)
2. *How to Estimate Defect in White Fir in South-Central Oregon* (38)
3. *How to Estimate Defect in White Fir in Southwest Oregon* (39)

These guides were authored by Paul Aho of the PNW Station and James Hadfield of Forest Service, Region 6. They include photographs of each of the major and minor defects along with written descriptions of each defect and the recommended amount of deduction.

Broken Tops



Basal Injuries

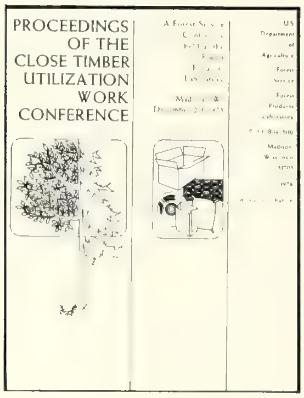
Each guide in this series is a valuable tool for those who cruise timber. The guides are based on extensive field research which also includes a study of decay in Englemann spruce in the Blue Mountains of Oregon and Washington (40) and ponderosa and sugar pine logs (41).

Slide-tape instructional programs have also been developed for defect estimation in grand fir in the Blue Mountains, white fir in south-central Oregon, and white fir in southwest Oregon. Information concerning the rental or purchase of these training aids can be obtained from:

Forestry Instructional Center
c/o Forestry Business Office
School of Forestry
Oregon State University
Corvallis, Oregon 97331
Phone: 503/754-1702 or
FTS: 424-1702.

forest residues

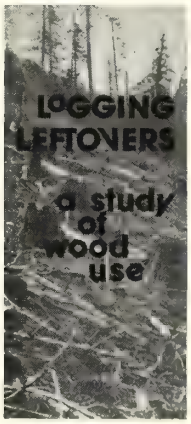
general



PROCEEDINGS
OF THE
CLOSE TIMBER
UTILIZATION
WORK
CONFERENCE

Proceedings of the Close Timber Utilization Work Conference, Madison, Wisconsin (42)

A 94-page report contains presentations by 16 Forest Service people on the subject of forest residues and how to improve wood utilization. The report is the proceedings of a Forest Service Conference held at the Forest Products Laboratory in Madison, Wisconsin, in December 1975. All aspects of residues are discussed, including volumes, utilization potential, research needs, and timber sale considerations.



LOGGING
LEFTOVERS
a study
of
wood
use

Logging Leftovers

A small brochure describes a cooperative study between the Forest Service and Simpson Timber Company. Conducted in the Sustained Yield Unit of the Olympic National Forest near Shelton, the study is examining ways to create less residue during the timber harvesting. It will also explore new ways to use more of the wood that remains after logging in the Douglas-fir region. Cooperators hope to increase wood utilization and improve the looks of recently logged areas.

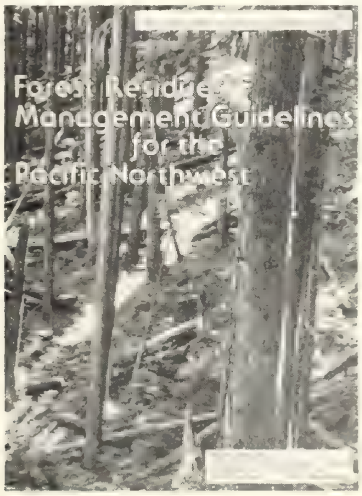
See *Logging Leftovers, A Study of Wood Use* (43).

Environmental Effects of Forest Residues Management in the Pacific Northwest—A State of Knowledge Compendium, edited by Owen P. Cramer (44)

If you want to know about forest residues, this is the place to begin. In this compendium, 27 research scientists summarize the state of knowledge of the effects of forest residues and residue treatments on the components of the forest environment: soil, water, air, fire, esthetics, forest growth, animal habitat, insects, and disease. Researchers question some current management practices and identify areas for research where current knowledge is lacking.

This summary provides a basis for:

1. Guiding forest resource managers in their selection of residue treatment alternatives.
2. Planning an intensive, broad research and development program on effects of residue and residue treatments.
3. Designing equipment for treating forest residue.



Forest Residue Management Guidelines for the Pacific Northwest

Forest Residues Management Guidelines for the Pacific Northwest, by Pierovich, Clarke, Pickford, and Ward (45)

This 273-page book provides practical guidelines that will help foresters make management decisions about treatment of forest residues. A unique keying system helps guide users to the solution of their particular land management problem.

The guidelines are based on the information gathered for the residues compendium listed earlier. Both publications were prepared with the cooperation of foresters, scientists, and technical specialists representing several agencies and private landowners. Recommended guidelines consider all the resources of the forest and are given for both public and private ownerships.

Choosing Forest Residue Management Alternatives, by John M. Pierovich and Richard C. Smith (46)

Residue management must become part of the overall scheme of forest management. This paper discusses residue management from the standpoints that forest residue is: (a) potentially usable wood fiber, (b) a serious fire hazard, (c) an obstruction to forest use and management, and (d) a solid waste disposal problem that attracts much public attention.

A schematic thought process is suggested whereby land managers may compare alternative residue treatments in terms of their expected costs and benefits.

volume & measurement

Logging Residues on Douglas-fir Region Clearcuts—Weights and Volumes, by John D. Dell and Franklin R. Ward (47)

Logging residue weights and volumes are given for a sample of clearcuts in the Douglas-fir region of western Oregon and Washington. A total of 1,509 acres were sampled in the study.

Results show the large volumes of logging residue being left in the Douglas-fir forests of the Northwest. The mean gross volume of residues on the 30 units sampled was 7,430 cubic feet per acre. Slash fuel weights ranged from 32 to 227 tons per acre.

Logging residue [illegible]

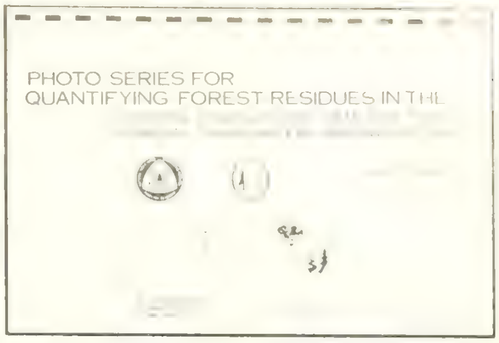


PHOTO SERIES FOR
QUANTIFYING FOREST RESIDUES IN THE

Photo Series for Quantifying Forest Residues in the: Coastal Douglas-fir-Hemlock Type; Coastal Douglas-fir-Hardwood Type, by Wayne G. Maxwell and Franklin R. Ward (48)

Measurement of forest residues has been costly and time consuming in the past. Photo Series provides a fast, easy, inexpensive way to quantify and describe existing and expected residues—adequate for most management needs.

Photo Series is an array of colored photos showing different residue loading levels generated from like timber types and cutting practices. Each photo is supplemented with data and information such as measured quantities by size classes, stand characteristics, harvest and treatment methods employed, and fuel ratings.

The photo series is a comparative tool and communication aid. Users can:

- Inventory residues by matching characteristics on the ground with like characteristics in a photo and extracting quantities from the accompanying photo series data sheet.
- Predict loadings and appearance of planned cutting or treatment areas by matching planned volume removal and treatment methods with like information on a photo series data sheet, extracting residue quantities from this sheet, and viewing the accompanying photo.
- Determine desired residue levels to meet land management objectives, irrespective of professional specialty, by studying photo series to visualize described quantities, evaluating benefits and impacts of various quantities, and discussing most advantageous quantities with other participants.

A companion publication for predominant pine types in the Pacific Northwest is also available (49).

Logging Residue in Washington, Oregon, and California—Volume and Characteristics, by James O. Howard (50)

This report makes available data on the volume and characteristics of logging residue resulting from 1969 logging operations in Oregon, Washington, and California.

Highest volumes of logging residue are found on clearcuts in the Douglas-fir region of western Oregon and western Washington. Average gross volume of residue in this region ranged from 4,548 cubic feet per acre on national forest land to 1,491 cubic feet per acre on private land.

Total net volume for all owners in this region was estimated to be about 460 million cubic feet for 1969. The lowest volumes were found in the ponderosa pine region of eastern Oregon and eastern Washington. In California, gross volume averaged 1,905 cubic feet per acre for private lands and 1,460 cubic feet per acre for National Forests.

For earlier reports on logging residues, see also items listed in the bibliography (51).

Jim Howard

Measurement of Logging Residue—Alternative Applications of the Line Intersect Method, by James O. Howard and Franklin R. Ward (52)

Alternative designs are outlined for using the line intersect method to measure logging residue. These methods can be used to estimate logging residue volume within ± 15 to 20 percent of the actual volume. Results also indicate that it will be costly to increase the accuracy of estimates beyond that point.

Characteristics of Residues in a Balloon Logged Area of Old-Growth Douglas-fir, by W.Y. Pong and John W. Henley (53)

The residues in a 44-acre old-growth Douglas-fir stand in the Oregon Cascades were examined before and after the area was clearcut and balloon logged.

The amount of residues on the ground increased from more than 5,000 cubic feet per acre before logging to more than 8,000 cubic feet after logging—a 53-percent increase. Not all size classes of residues increased in volume. In fact, there was a noticeable decrease in the larger classes, indicating that some of the material classed as residues had been yarded out.

If we define usable residues as material which can be yarded without breaking up, at least 10 percent sound, 3 inches and greater in diameter, and at least 4 feet long, then more than 80 percent of the prelogging residues and nearly 70 percent of the logging residues could have been used.

treatment

High-Lead Scarification: An Alternative for Site Preparation and Fire-Hazard Reduction, by Franklin R. Ward and James W. Russell (54)

Scarification is evaluated as an alternative to slash burning in preparing for planting (a) a recently logged site, and (b) a previously treated site that had been taken over by a dense stand of brush.

The scarifying tool was a 1½ by 4½-foot steel cylinder, concave on both ends, and filled with concrete. It was connected to a cable system employing a yarder with a 25-foot tower and a specially modified crawler tractor which served as a mobile tailblock. The weighted cylinder was dragged back and forth between the tower and the tractor to scarify, break, or masticate the residue.

Using this system, it took 43 hours to scarify 34 acres of one unit and about 42 hours to scarify 29 acres of the second area. Scarification reduced the slash considerably and resulted in more exposure of mineral soil. Total cost of treating the areas was $244 per acre and $264 per acre, respectively.

Evaluations on Accelerating Wood Decomposition in the Field, by Franklin R. Ward (55)

Douglas-fir logging residues may retard forest regeneration and increase the fire hazard in Pacific Northwest forests. Since decay of Douglas-fir wood is relatively slow, this condition can persist for many years.

The objective of this study was to see if wood decay could be speeded up by treating it with various chemicals: ammonium phosphate, urea, asparagin, 2,4-D and 2,4,5-T, and a plastic spray to keep moisture in.

They just didn't work. Researchers do not recommend these materials for residue reduction.

Semipermanent Fire Retardants—Are They Needed? by Hugh R. McLean (56)

A semipermanent fire retardant would be a valuable tool in building lines around a prescribed burn area. A survey of fire management specialists indicated that retardant lines could replace 25 to 500 miles of conventionally constructed control lines annually in each of the National Forest Regions responding.

Forest Service fire laboratories, in cooperation with one or more of the interested fire retardant chemical manufacturing companies, are urged to undertake additional research and development work.

utilization

Flows of Mill Residues to Pulp and Board Manufacturers, Washington, Oregon, and California, 1968, by Grover A. Choate (57)

Twelve million tons of residues were generated by lumber and veneer and plywood mills in the Pacific Northwest in 1968. Of the 10.3 million tons that went to domestic mills, 83 percent went to pulpmills (average distance 82 miles) and 17 percent to board mills (30 miles); 74 percent was shipped by lumber mills (68 miles) and 26 percent by veneer and plywood mills (88 miles). Fifty percent of residues to domestic mills went by truck (37 miles), 35 percent by rail (147 miles), 6 percent by barge (59 miles), and 9 percent by onsite transport (1 mile).

Nine million tons of wood residues from sawmills and veneer and plywood mills were either unused or went for fuel in 1968.

Jack Grantham

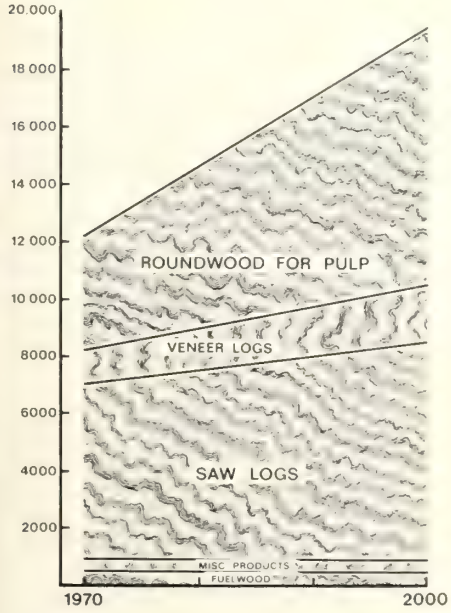
Energy From Wood

The energy of the sun is locked inside every living thing. Trees are an abundant source of this energy, and there is renewed interest in converting wood, especially logging residue, to energy.

What are the possibilities for using wood waste for energy in the Pacific Northwest where both wood and water resources are relatively abundant? A preliminary study indicates that generation of electricity from wood residue is not generally practical here; at least at this time. However, small scale power production may be feasible for individual plants that have a need for both process steam and electric power. The major drawback is the high cost of collecting and transporting wood to the conversion site.

See *Energy and Raw Material Potentials of Wood Residue in the Pacific Coast States—A Summary of a Preliminary Feasibility Investigation,* by John B. Grantham, Eldon M. Estep, John M. Pierovich, Harold Tarkow, and Thomas C. Adams (58).

See also a report titled, *Potentials of Wood for Producing Energy,* by John B. Grantham, and Thomas H. Ellis, a reprint from the *Journal of Forestry* (59).



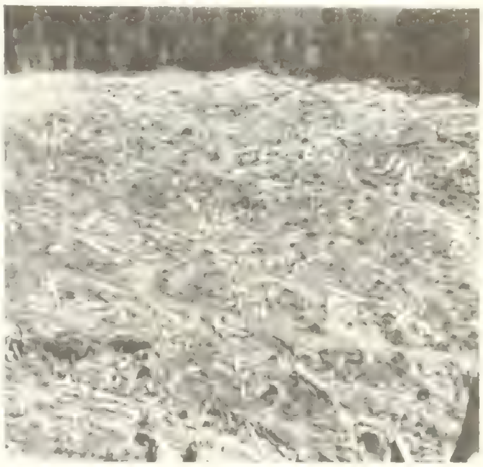
Projected consumption, 2000.

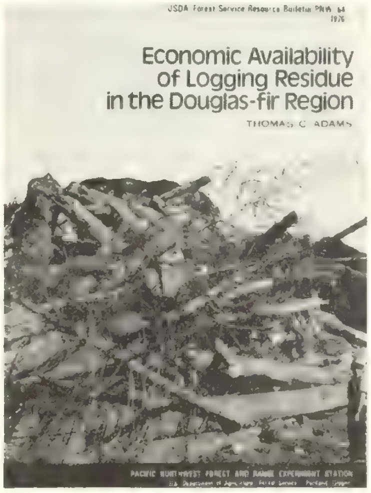
Review of the Logging Residue Problem and Its Reduction Through Marketing Practices, by Thomas C. Adams (60)

Air quality regulations adopted in the last 10 years require reduced burning of logging slash. New ways are being sought to reduce the quantity of logging residues by other means.

A review of potential marketing practices designed to reduce logging residue explored several approaches. These include stronger removal incentives or treatment requirements in the timber sale contract, more efficient harvesting methods, and development of expanded markets for utilization of residue type material.

For example, alternative sale arrangements can include such things as reduced stumpage charges for low quality logs or required yarding of unutilized material to the landing or to some stockpiling or disposal point. Improvements in harvesting methods can be designed and specified to create less breakage. Also, more wood fiber will be made available through more careful bucking, sorting, and grading, and coordination with the diversity of available utilization outlets.





USDA Forest Service Resource Bulletin PNW 64
1976

Economic Availability
of Logging Residue
in the Douglas-fir Region

THOMAS C. ADAMS

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. Department of Agriculture Forest Service Portland, Oregon

Economic Availability of Logging Residue in the Douglas-fir Region, by Thomas C. Adams (61)

Logging residue from harvest operations in old-growth forests of the Douglas-fir region contains much sound wood fiber. Economic availability of each piece, however, depends on its size, condition, location, existence of a market for that kind of material, and an adequate price to cover costs.

A study of one year's harvest estimated 185 million cubic feet of logging residue in western Washington and western Oregon had a positive conversion value in 1970, if it had been yarded at the time of regular logging, and if there had been no stumpage charge for such material. Lack of utilization, however, is considered to be due to such factors as the operator's lack of suitable equipment for handling small logs or pieces, lack of local markets, general market instability, and problems of setting specifications, scaling, and pricing.

PER-ACRE PRICING
ITS EFFECT ON
LOGGING RESIDUE

Per-Acre Pricing—Its Effect on Logging Residue, by Thomas E. Hamilton, James O. Howard, and Thomas C. Adams (62)

Do timber sale procedures affect the amount of wood residue left in the forest after logging? This paper compared two methods used by the U.S. Forest Service in Oregon and Washington for selling standing timber. One method (scale sales) applies a set price per thousand board feet, by species, to the log scale or the measured amount of timber removed. The other method (per-acre material or PAM sales) sells all logs below a given net volume for a lump sum per acre with larger logs sold on a scale basis.

The purpose of the PAM method is to encourage the logging operator to remove more of the low value material that might otherwise be left as logging residue. Results of this study showed 14.1 percent less residue for the PAM sales. This was a significant difference at the 10-percent probability level, but not at the 5-percent level; the authors concluded this was not strong statistical evidence that a real difference exists between the two methods.

Utilization of Douglas-fir Bark, by J. Alfred Hall (63)

About 1.5 million tons of bark is produced annually in the Douglas-fir region as a result of timber harvesting operations. Existing outlets are taking substantial quantities of bark, but much more is wasted or used only for fuel. The physical and chemical makeup of old-growth Douglas-fir bark is unique and increased attempts should be made to find uses for it.

Whole bark is used for power fuel, domestic fuel, charcoal manufacture, board and tile manufacture, and for agricultural use. Physically, bark is made up of three principal fractions: cork, fiber, and fines. A survey is given of the many efforts to develop markets for these materials.

Twenty years experience by the Weyerhaeuser Company in producing and marketing the physical fractions has resulted in a continuing business of modest size. One of the best markets has been for fines in drilling muds. Both the cork fraction and the fiber fraction have also been used extensively. The market for these products, however, has been uneven. Further refining of the chemical properties of bark might produce better results.

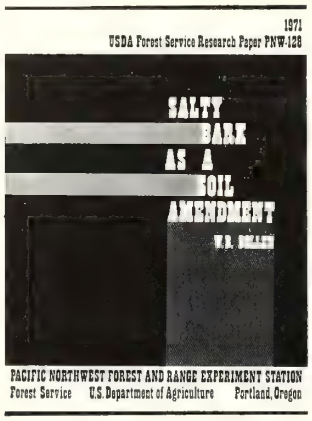
For another report on the same subject, see *Bark—Old and New,* a keynote speech by J. Alfred Hall at a conference on Converting Bark into Opportunities, held in 1971 at Oregon State University (64).

Sour Sawdust and Bark—Its Origin, Properties, and Effect on Plants, by W.B. Bollen and K.C. Lu (65)

Milk sours as it gets old and so does sawdust! Acetic acid and other volatile organic acids accumulate as a result of fermentation of sawdust and bark in large storage piles. Such sawdust should not be used for horticultural purposes without aeration or addition of lime to reduce the volatile acids.

A highly pungent odor means the sawdust should not be used. Usually the nose will guide the user. But a simple pH test kit and a reading below about 3.5 also means trouble.

Sawdust pile with sour center.



1971
USDA Forest Service Research Paper PNW-128

SALTY
BARK
AS A
SOIL
AMENDMENT

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
Forest Service U.S. Department of Agriculture Portland, Oregon

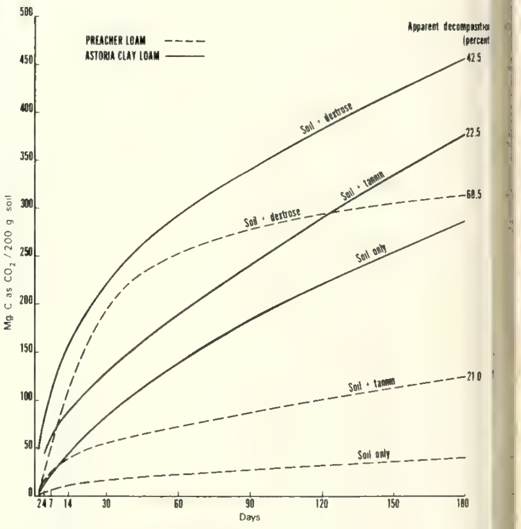
Salty Bark as a Soil Amendment, by W.B. Bollen (66)

Salt is toxic to plants, and bark from logs that have soaked in salt water for a long time may be harmful to plants when applied at the usual rate of about 40 tons per acre. Salt leaching may injure sensitive plants if the salt is concentrated in the upper root zone.

Salty bark that is ground to the nominal ¼ to ½-inch size commonly used for horticultural purposes would be less hazardous as a mulch than if incorporated in the soil.

Douglas-fir Bark Tannin Decomposition in Two Forest Soils, by W.B. Bollen and K.C. Lu (67)

Addition of tannin, from Douglas-fir bark, to two greatly different forest soils produced no evident harmful effects. However, a moderate decrease in nitrification caused by the tannin should be considered when bark is used for agricultural purposes. This feature might even be useful in watershed management because bark on forest soils might lower nitrate production and thus decrease the hazard of nitrates in water supplies fed by forest streams.



Influence of Douglas-fir bark tannin and dextrose on carbon dioxide production.

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fire

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Only limited research has been done at the PNW Experiment Station on forest fire problems. Of the studies that have been conducted, most relate either to the effects of fire and prescribed fire on the environment, or to fire weather and fire danger rating.

The Forest Service does have an extensive fire research program, however. That work is conducted at three fire laboratories throughout the country. Information may be obtained from the following:

Northern Forest Fire Lab
University of Montana Campus
Drawer G
Missoula, Montana 59801

Forest Fire Lab
P.O. Box 5007
Riverside, California 92507

Southern Forest Fire Lab
Georgia Forestry Center
P.O. Box 5106
Macon, Georgia 31208

wildfire

fire weather

Effect of Fire Whirlwind Formation on Solid Fuel Burning Rates, by Martin, Pendleton, and Burgess (1)

Fire whirlwinds are one of the most disastrous phenomena associated with forest or urban fires. In addition to their high wind velocities and ability to transport firebrands, fire whirlwinds also cause the burning rates of woody fuels to accelerate from 1.5 to over four times as fast as without the whirlwind.

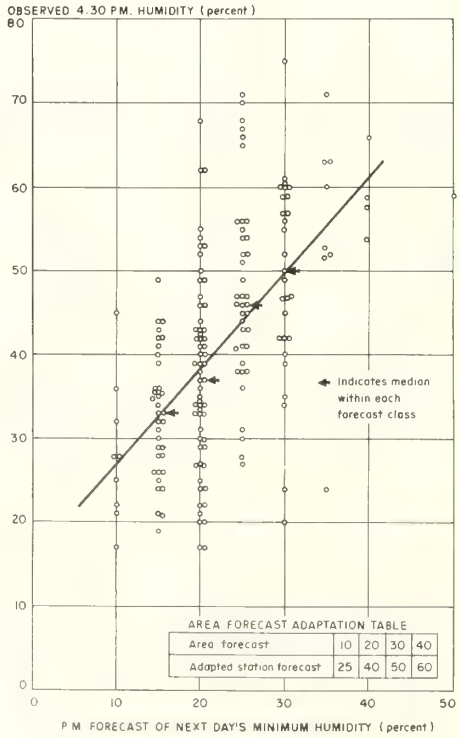
Predicting Burning Index

Considerably more research is needed before fire weather and fire danger can be predicted with enough accuracy to adequately meet the needs for forest fire control.

In this study, researchers explored the praticality of using several tabular and graphical aids to convert area forecasts and local observations of relative humidity and wind speed into predicted values for individual fire-danger stations. Four different aids were tested: (a) aids for adapting area forecasts of wind speed and relative humidity, (b) a procedure for predicting wind speed, (c) aids for predicting fuel moisture, and (d) routine statistical procedures for predicting wind speed, fuel moisture, relative humidity, and burning index class.

Some of the aids showed promise, and some improvements were made during the course of the study. But, more important, the difficulty of the task has emphasized the need for more research on the problem.

See *Using Fire-Weather Forecasts and Local Weather Observations in Predicting Burning Index for Individual Fire-Danger Stations,* by Owen P. Cramer (2).

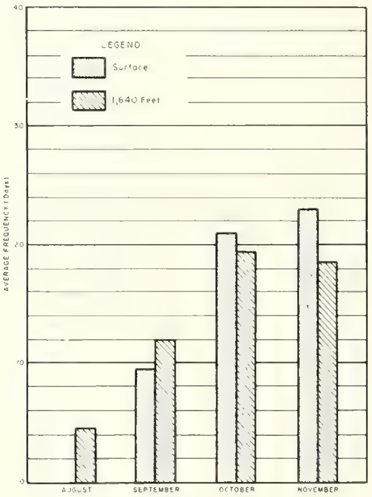


Example of humidity forecast adaptation aid and worksheet.

Frequency of Dry East Winds Over Northwest Oregon and Southwest Washington, by Owen P. Cramer (3)

There is a close relation between occurrences of severe easterly winds and large forest fires in northwest Oregon and southwest Washington. With the east wind comes the dreaded combination of low humidity and high wind that in the past has whipped small fires into conflagrations such as the Tillamook fire of 1933 and the fire that burned Bandon in 1936. These easterly winds are of the **foehn** type, typically dry because they are downslope winds.

Cramer discusses the situations that produce dry east winds, and gives data on the frequency of major and extreme east winds in three elevation zones.



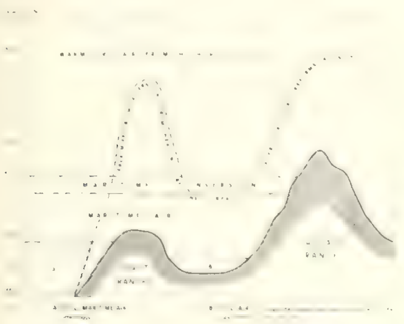
Comparison of frequencies of major easterly winds at 1,640 feet over Portland with major surface winds in northwest Oregon and southwest Washington during 1934-41 and 1948.

Relation of Number and Size of Fires to Fire-Season Weather Indexes in Western Washington and Western Oregon, by Owen P. Cramer (4)

In this study, fire-season weather indexes for western Oregon and western Washington were found to be correlated with actual fire occurrence. Equations given here make it possible to compute the number of man-caused fires and the proportion of all fires in each of three size classes that might reasonably have been expected under actual fire weather conditions.

Adjustment of Relative Humidity and Temperature for Differences in Elevation, by Owen P. Cramer (5)

Weather patterns in mountainous terrain are so complex that general forecasts are not always useful when used to predict weather in the mountains. But much information about temperature and humidity can be obtained by adjusting available observations or forecasts for any difference in elevation from the forecast or observation point.



Typical strata of air over western Oregon and western Washington on a summer morning.

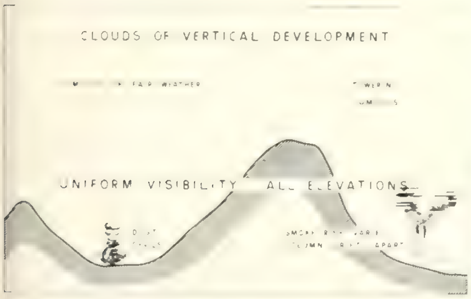
This paper provides charts that make it possible to:

(a) Determine the vertical extent of layers in which mixing is present (unstable layers) and of layers in which there is no mixing (stable layers).

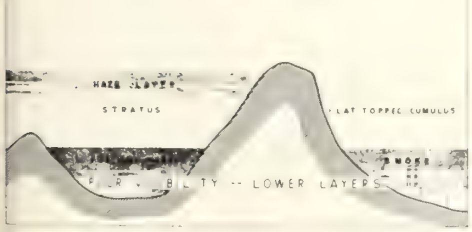
(b) Adjust temperature and humidity between elevations within mixed layers.

(c) Predict afternoon valley temperatures and humidities from morning observations at peak stations.

(d) Estimate humidities at any level within the mixed layer beneath cumulus clouds.


CLOUDS OF VERTICAL DEVELOPMENT
FAIR WEATHER
UNIFORM VISIBILITY ALL ELEVATIONS
APART

Indicators of unstable air.



Indicators of stable air.

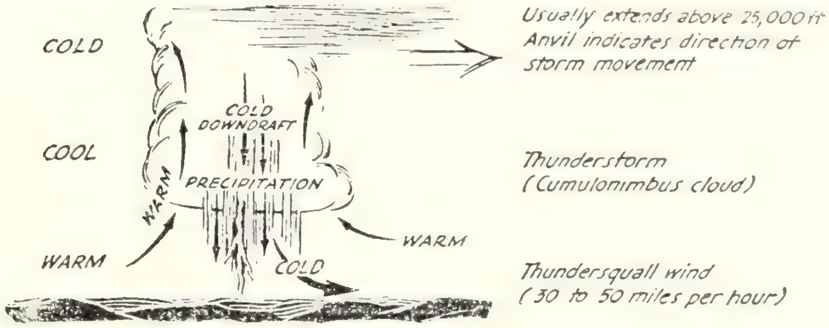
Recognizing Weather Conditions That Affect Forest Fire Behavior, by Owen P. Cramer (6)

A nice discussion of the various conditions that make up fire weather. Emphasis is on discussion of factors that can cause violent or erratic fire behavior and subsequent fire "blow up." The following conditions are described:

- stable air
- inversion
- unstable air
- turbulence
- gustiness
- convection
- thundersquall
- whirlwind
- dust whirl
- fire whirlwind
- fire storm

As an example, the following description and diagram is given for a thundersquall:

Thundersquall The sudden wind that blows outward from beneath a thunderstorm. Such a wind originates in the area of heaviest precipitation in a cumulonimbus cloud, a convective cloud type that occurs in unstable, moist air. Air, cooled by precipitation, descends from the cloud and fans out at the surface. The thundersquall usually occurs with a well developed thunderstorm and hits suddenly with speeds averaging 30 to 50 miles per hour for a period of several minutes. The thundersquall may occur beneath a thunderstorm from which no precipitation reaches the ground, and may extend outward a mile or more ahead of the storm edge. These sudden, strong winds may sweep a fire far beyond its confines before the rainy section of the thunderstorm arrives. If the rain evaporates before reaching the ground, the fire may continue to burn unchecked.


COLD
COOL
WARM
COLD DOWNDRAFT
PRECIPITATION
WARM
WARM
COLD
Usually extends above 25,000 ft
Anvil indicates direction of storm movement
Thunderstorm (Cumulonimbus cloud)
Thundersquall wind (30 to 50 miles per hour)

Thundersquall.

occurrence and detection

Forest Fires in Western Oregon and Western Washington, by William G. Morris (7)

The first anniversary of the great Tillamook fire of 1933 prompted William G. Morris to write this fascinating report on early forest fires for the *Oregon Historical Quarterly.* It's all here. . .the drama and heartbreak that is best summarized here by a few excerpts:

1845: "When the fire came, after several smoky days, the Indians had to leave all their belongings in order to escape down the river."

1846: "Salmon River John, an Indian who was accustomed to weigh his words carefully, bore witness that the fire was so great in the Yaquina Bay region that the flames leaped across the river, that many of the Indians perished and that only those were saved who took refuge in the water."

1864: "Never, since the white man trod the sod of southern Oregon, has there been so much fire in the mountains as during the past few weeks. From north of the canyon to the Siskiyous, the fire has been raging with increased fury. Much of the sickness which prevails among us at present is attributed to the heated state of the atmosphere and the immense volumes of smoke ever created by the vast fires."

1868: "We learn from Captain Cosgrove, of the Mary Woodruff, that the fire is raging extensively in the woods around Bellingham Bay. . .The sawmill took fire and the coal miners all turned out en masse and succeeded after strenuous efforts in saving the mills. . .The coal company has lost some thousands of dollars worth of hewn timber which they had in the woods. . ."

Lightning Storms and Fires on the National Forests of Oregon and Washington, by William G. Morris (8)

This unique and still valid study of thunderstorm occurrence, movement, and lightning production characteristics scrutinizes the summer, forest-fire starting storms common over the forested mountainous areas of Oregon and Washington.

This analysis is based on more than 6,000 reports by U.S. Forest Service lookouts who observed some 1,500 separate thunderstorms in the summers of 1925 to 1931. From these reports, individual storm tracks were reconstructed and the storms' characteristics determined. Morris found that:

- Sixty-six percent of all lightning fires are started on ''general'' storm days.
- There were no preferred ''breeding'' spots and no preferred storm tracks.
- An ''intermediate'' or ''general'' storm day has a 40 percent chance of being followed by another similar day.
- There are definite zones of lightning storm frequency.
- The summer average of 23 to 27 days with thunderstorms far exceeds the frequencies for the more densely populated areas of the two states.
- Ninety percent of the storms developed between 10 a.m. and 10 p.m.
- Most storms had tracks 11-60 miles long, moved at 6-20 mph, and travelled in a northerly direction.

Records and Experience of Discovering Fires from Aircraft, by William G. Morris (9)

An early report documenting the benefits of forest fire detection from aircraft. During the period 1950-56, about 250 fires were discovered by aerial observation on four national forests in the Pacific Northwest. Ninety-three percent were only small spots when discovered.

Personnel kept special records concerning fires discovered and fires missed by aerial patrol, method of using the eyes while looking for fires, and conditions that might affect efficiency of an aerial observer. Records are from four national forests: the Wallowa-Whitman, Okanogan, Mt. Baker, and Siskiyou.

prescribed burning

Use of Fire in Managing Forest Vegetation, by George R. Fahnestock (10)

In using fire, man has sought to emulate nature. He has observed that wildfires produce widely varying effects in response to the many combinations of fuel, weather, and topography in which they burn. Even fires that are remembered for their high intensity and destructiveness almost invariably contain areas of low-intensity burning where little damage or even some benefit results. Consequently, man has learned to use fire in various intensities, according to his purpose. This paper reviews briefly the purposes, techniques, costs, and consequences of man's use of fire to manage forest vegetation.

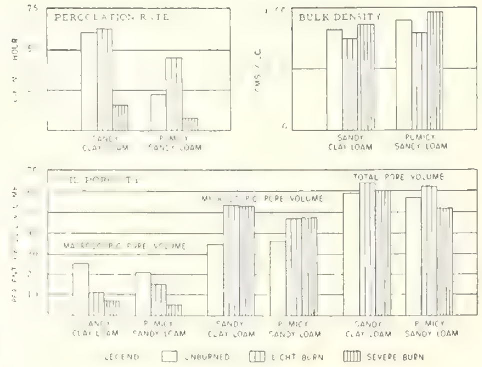
Effects of Slash Burning on Some Soils of the Douglas-fir Region, by Robert F. Tarrant (11)

Effects of slash burning on soils are important in order to maintain productivity of the site. Three classes of surface soil condition following burning are recognized: unburned, light burn, and severe burn. Each class is defined and the effects studied.

Information gained from this study indicates that severe burning does damage the soil, but usually only a small percentage of the area is severely burned. Severe burning is most often associated with heavy concentrations of slash, which will be less common on new clearcut areas in the Douglas-fir region as old-growth harvest is reduced.

An intensive sampling of 10 clearcut and burned areas gave these results:

Surface condition	Percent of total area
Unburned	47.1
Light burn	46.9
Severe burn	2.8
Non-seedbed (rock, etc.)	3.2



Changes in physical soil properties after slash burning.

Some Effects of Logging and Slash Burning on Physical Soil Properties in the Corvallis Watershed, by C.T. Dyrness, C.T. Youngberg, and Robert H. Ruth (12)

The effects of slash burning on forest soils are discussed. This study indicates that light or moderate burning will not cause much change in soil properties. In severely burned portions, however, scientists found a consistent and significant change in the character of the surface soil. Severe burn was found on only about 8 percent of the three units examined, which was probably a higher percent of severe burn than normal in the Douglas-fir region.

Severe burning caused loss of silt and clay and a corresponding increase in sand components in the soil. Organic matter was also reduced, and the percentage of aggregates in the top two inches was lowered.

This paper is really an introduction to slash burning and its effects on soil properties. The authors indicated that results should be applicable over a substantial part of the Douglas-fir region, but that only three soil types were sampled.

Fire Ecology in the Pacific Northwest

The proceedings of the Fifteenth Tall Timbers Fire Ecology Conference held in Portland in October 1974 is a landmark publication on fire ecology in the Pacific Northwest. Papers on many aspects of fire ecology are included. The following are available as reprints from the Experiment Station:

- *Fire in the Pacific Northwest—Perspectives and Problems,* Robert E. Martin, Dar D. Robinson, and Walter H. Schaeffer.
- *Development of Vegetation After Fire, Seeding, and Fertilization on the Entiat Experimental Forest,* Arthur R. Tiedemann and Glen O. Klock.
- *Soil-Water Trends Following Wildfire on the Entiat Experimental Forest,* G.O. Klock and J.D. Helvey.
- *Some Climatic and Hydrologic Effects of Wildfire in Washington State,* J.D. Helvey, A.R. Tiedemann, and W.B. Fowler.
- *An Approach to Predicting Slash Fire Smoke,* D.V. Sandberg and S.G. Pickford.

The entire proceedings is available as a report (13) from the Tall Timbers Research Station, Route 1, Box 160, Tallahassee, Florida 32303.

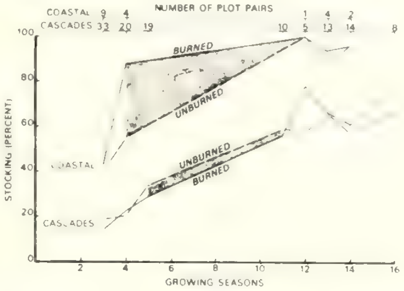
Effects of Slash Burning in Overmature Stands of the Douglas-fir Region, by William G. Morris (14)

The established management system of clearcutting the tall, dense, overmature forests of the Douglas-fir region of western Oregon and Washington usually leaves great quantities of debris after all merchantable wood is removed. In areas where the stands contained much rot and other defect, the slash may total 100 tons or more per acre.

National forests of the Douglas-fir region contain about 3 million acres of stands more than 150 years old. Most logging on national forests for at least the next 50 years will be in these stands. Patches, usually of about 30 to 60 acres, are clearcut. In the past, the slash on most of them has been burned under prescribed conditions to reduce fire hazard, prepare seedbed or planting site, and reduce brush competition with tree reproduction.

Some foresters have doubted the efficacy of slash burning for the stated purposes. Concern with the possible contribution of slash burning to air pollution has further stimulated reviews of the benefits and harm of burning.

In this study, it was found that slash fires consumed nearly all fine fuels, left nearly all logs, and severely burned less than 6 percent of the soil surface. Burning significantly reduced the fire hazard for as much as 12-16 years. In addition, burning changed the species composition of brush and herbage and reduced brush cover for a few years (except where *Ceanothus* invaded), but did not affect total herbaceous cover. Nor did burning affect the number of young seedlings that became established after the slash fires.

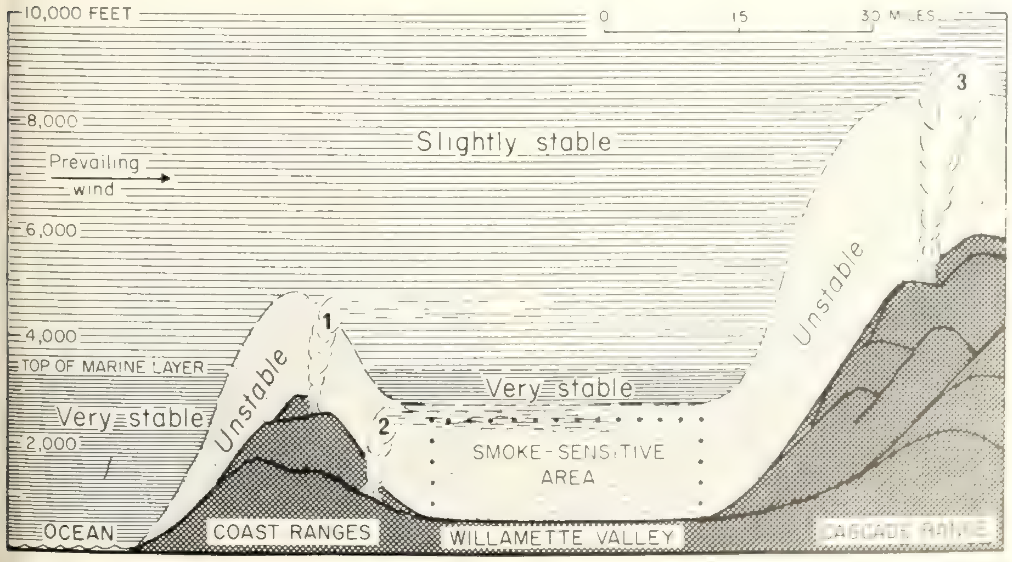


Percent of stocked 4 milacre areas on burned and unburned plots, by growing seasons.

Cooperative Management of Smoke from Slash Fires, by Owen P. Cramer and Howard E. Graham (15)

In Oregon and Washington, a cooperative system has been developed for maintaining reasonable air quality in connection with forest slash burning. Cooperating are the Department of Environmental Quality, the Oregon Forestry Department, Oregon Forest Protection Association, U.S. Bureau of Indian Affairs, U.S. Forest Service (and more recently, the Department of Natural Resources, Washington).

During the first season's operation, the Oregon Department of Forestry reported: "During this period, there were 1,226 prescribed burns involving 51,600 acres (2 million tons) under the smoke management program. It appeared that no major pollution problems were encountered." Slash burning can be done with a minimum of air pollution by controlling the time, location, and quantity of burning.



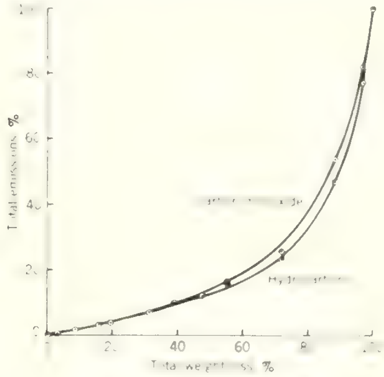
Atmospheric stability conditions over western Oregon on a typical warm-season afternoon

Emissions from Slash Burning and the Influence of Flame Retardant Chemicals, by D.V. Sandberg, S.G. Pickford, and E.F. Darley (16)

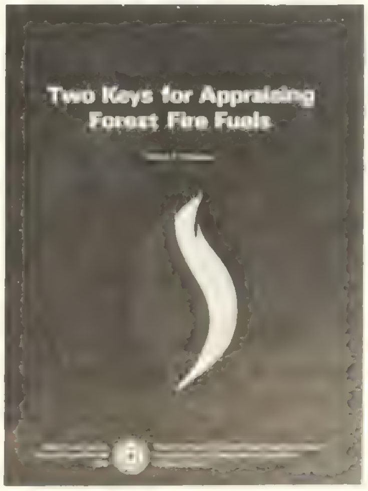
A very technical report concludes that the smoldering phase of combustion is of major importance in producing pollution during slash burning. Most of the fine fuels are burned prior to the smoldering phase, and most objectionable gaseous emissions occur during the latter phase.

The conclusion is that high intensity burning and rapid extinguishment will result in less gaseous pollution.

Researchers also tested the fire retardant DAP to see if it would reduce pollution. Although less fuel actually burned in DAP-treated fuel beds, production of all pollutants went up—including the particulate fraction.



Relation of the proportion of total fuel consumed to the proportion of total pollutant emitted for nine untreated fuel beds



Two Keys for Appraising Forest Fire Fuels, by George R. Fahnestock (17)

Forest fire fuels are characterized in a new way. Keys are given that enable users to recognize and evaluate fire spread and crown fire potential on the basis of readily observed forest fuel characteristics.

The paper is not a complete fuel appraisal system in itself. But the framework used here can also be used to develop keys for rating ignition probability, fire intensity, and resistance to control.

Slash Fire Atmospheric Pollution, by Fritschen, Bovee, Buettner, Charlson, Monteith, Pickford, Murphy, and Darley (18)

A primary objective of this study was to investigate slash burning in relation to air pollution. Specifically, the researchers sought to determine the effect of fire temperature on pollution (for example, do low temperature fires cause more pollution than hot ones), and to determine if the principal features of a field test can be modeled in the laboratory.

Conclusions are that:

(a) Air pollution can be minimized by a hot fire that creates a strong convection column under conditions favorable for rapid atmospheric dispersion. The fire should be of short duration to consume the smaller fuel only.

(b) Results also suggest that broadcast fires can be modeled in the laboratory with respect to burning characteristics, gaseous and particulate emission from different fuel density, packing, composition, and method of ignition.

Particle Sizes in Slash Fire Smoke, by David V. Sandberg and Robert E. Martin (19)

Burning of forest fuels produces an estimated 23.7 percent of the particulates emitted to the atmosphere each year and 6.9 percent of the hydrocarbons. Increased public awareness of air pollution has focused unfavorable attention on the burning of logging slash. The burning of 6.3 million metric tons of forest residue in Oregon and Washington annually releases 45,000 metric tons of hydrocarbons and 76,000 metric tons of particulate matter into the atmosphere. Wildfires contribute even more, but accurate estimates are difficult to make.

This laboratory study has attempted for the first time to measure the size of particles that are likely to result from forest burning. Studies showed that 82 percent of particulate mass was less than 1 micrometer in diameter. Scanning electron microscopy showed four types of particles.

Forest Fuels, Prescribed Fire, and Air Quality, by J. Alfred Hall (20)

Smoke from forest wildfires or prescribed burns is often considered on a par with other emissions that might affect air quality. But enough is known about smoke from woody fuels to know that the biggest problem is with reduced visibility rather than addition of harmful pollutants to the environment. Visibility can be improved by proper preparation and timing of prescribed burning.

Much of the organic matter in smoke from forest fuels is similar to that which naturally enters the air—from decomposition of vegetation or from vegetative growth processes. Fire compresses these emissions into a shorter time.

The reduction in danger of forest conflagrations more than compensates for the temporary decrease in visibility from prescribed burning.

Predicting Weights of Douglas-fir Slash for Material up to 3 Inches in Diameter, by Woodard, Pickford, and Martin (22)

The weight of Douglas-fir slash can be predicted from tree diameter at breast height. This information can then be used to predict the amount of slash fuel that will be created by logging. The forest manager should find this useful in predicting the amount of treatment needed for brush disposal in laying out timber sales and in evaluating treatment effectiveness.

Slash Fire Behavior Correlates With Fuel Moisture Indicator Stick Readings, by William G. Morris (21)

Good judgment is needed in order to decide when to burn slash west of the Cascades in Oregon and Washington. If conditions are not correctly analyzed, slash may not burn well enough to reduce the hazard; or it may burn too readily and damage soil or adjacent stands.

The following guidelines are given:

- Burn in fall when rain has moistened the bottom of the duff layer in slash area and in adjoining green timber.
- Burn more than 1 day after rain.
- Avoid periods of east wind.
- Burn when fuel moisture indicator sticks read about 14 percent in the slash area and 20 percent in the adjoining green timber.

With less than average fuel, a smaller proportion of fuel with cured needles attached, less slope, or less wind, fuel moisture stick readings should also be lower in the slash area to indicate satisfactory burning. With more than average fuel, slope, and wind, fuel moisture readings should be higher to reduce risk of spot fires.

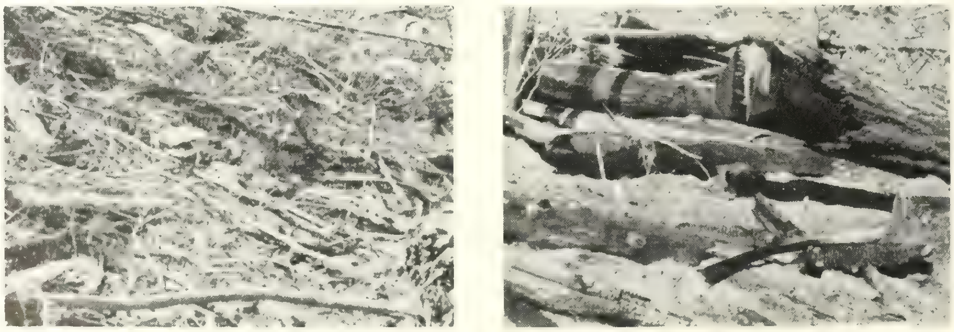
The guiding fuel moistures do not apply to periods within 1 day after rain nor to periods when deep duff is dry. Nor do they apply to burning in spring when deep duff and interior parts of logs and large limbs are more moist than in fall. Additional records are needed to determine guidelines for spring burning.

Variation in Vegetation Following Slash Fires Near Oakridge, by Harold K. Steen (23)

Photographic sequences illustrate how vegetation differed following logging and slash burning on two old-growth clearcuts in the Willamette National Forest near Oakridge, Oregon. Burned and unburned plots are shown for each area. Both areas were clearcut in 1949 and the slash burned in October of the same year. The two pairs of plots were selected because of the obvious differences in plant cover in the areas.

The difference in recovery of vegetation is striking. Thirteen years after the slash fire, conifers were well established in one area while heavy brush covered the other.

Readers should try to see an original (not a copy) of this report as the photographs are important to its understanding.



Unburned plots have a little trailing blackberry, starflower, Pacific rhododendron, and vine maple. Two percent of the burned plot had a hard burn (organic material destroyed and some soil coloration).

fire - bibliography

VILDFIRE

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alaska

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Map of Alaska showing major mountain ranges and general zone of ta[illegible]

general

Sourdough Science

Scientists from the Forestry Sciences Laboratory in Juneau and the Institute of Northern Forestry in Fairbanks are studying the complex world of the Alaskan forests. Both laboratories are making significant contributions to man's knowledge of these extensive forests. The information is being used by federal, state, and local agencies and native corporations to plan environmentally sound forest resource management programs.

Forestry research in Alaska is linked to two very different forest ecosystems. The taiga, or northern forests of the interior, contrast sharply with the luxuriant coastal forests. This brochure (1) gives a general overview of the research program in Alaska.

Alaska—the Great Land, edited by Clayton G. Rudd (2)

The Naturalist magazine presents its firs issue devoted to Alaska—32 pages of articles dealing with natural resource management in the 49th state. Many are by Experiment Station scientists. Les Viereck, noted northern ecologist, discusses the rol of fire in the taiga; Austin Helmers write on the climate, vegetation, and geology o the interior; and William R. Meehan discusses fish habitat and timber harvest i southeast Alaska.

Other articles are on planning Alaska's future, a trip by boat up the Inside Passage and a story on the Dusky Canada Goose—native-born Alaskan that goes south for th winter.

Copies are no longer available from th Experiment Station. Check your local library

Research Opportunities and Needs in the Taiga of Alaska, by Austin E. Helmers and Charles T. Cushwa (3)

An appraisal of taiga (the northern forests of interior Alaska) environment research opportunities and needs was made based upon accomplishments since Alaskan statehood, current involvement of citizens in resource issues, information needs incident to the National Environmental Policy Act of 1969, and needs of new resource managing agencies and changing ownerships brought about by statehood and the settlement of aboriginal land claims. Research needs can best be met through a multidisciplinary interagency program. The program suggests closer coordination among several departments of the University of Alaska and number of state and federal agencies now conducting research. The urgency of research implementation is related to rapid change and diminishing opportunity t insure orderly development of Alaska's resources.

Environment information needs in th taiga cover five major problem areas:

- ecology
- fire effects
- water
- culture
- economics.

cientists in Alaska

Forest Service researchers in Alaska are sted in a brochure published by Region 10 n Juneau. It includes a photo and short iography for all research personnel at the orestry Sciences Laboratory in Juneau, and he Institute of Northern Forestry in Fairanks.

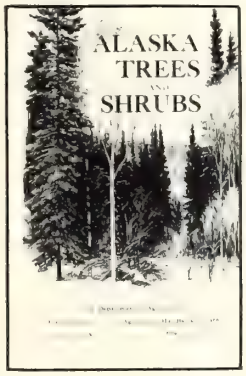
Copies may be obtained from the Office of nformation, Forest Service, Region 10, .O. Box 1628, Juneau, Alaska 99802. Ask for *Forestry Research Directory for Alaska* (4).

Publications List, 1963-1974

In 1967 the Northern Forest Experiment Station (NOR) became the Institute of Northern Forestry, which in turn became the Forestry Sciences Laboratory in 1972. Many of the earlier publications are now out of print, but may be requested on a loan basis. As the Forestry Sciences Laboratory became a division of the Pacific Northwest Forest and Range Experiment Station in 1967, all of its publications are now issued there and numbered in the PNW- series.

Order the bibliography from:
Forestry Sciences Lab
P.O. Box 909
Juneau, Alaska 99802

trees and shrubs



Alaska Trees and Shrubs, by Leslie Viereck and Elbert L. Little, Jr. (5)

$6.00 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; or from some book stores.

t's cold in Alaska (although not as cold as he North Pole where nothing much grows) and for that reason it is a region of relatively few trees and shrubs. At last count there were about 133 species, all included in this publication. Information is presented on identification (pen and ink drawings plus botanical descriptions), distribution, and uses.

If you're only visiting Alaska and $6.00 is too expensive, you might want to consider buying the shorter guide to trees only. Called *Guide to Alaska Trees,* by the same authors (6), it is 98 pages and includes information about 20 trees and a few shrubs. That one is available for $1.35 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; stock number 0100-03308.

Salmonberry (Rubus spectabilis) *winter twig at right.*

Dawn Redwood in Alaska, by A.S. Harris (7)

Dawn redwood, now native only in China, once flourished in the territory now known as Alaska, but way back in Mesozoic times. In 1948, R.W. Chaney of the "Save the Redwoods League" sent some 165 seedlings to Juneau to see if the species would grow there again.

Results of the experiment indicated that the present Alaskan climate is too harsh for the trees. Most of the seedlings died. By 1955 only five were known to be alive, and today (1973) only one is still alive on Japonski Island near Sitka.

Alaska-Cedar, by A.S. Harris (8)

Alaska-cedar, one of the most durable of American woods, has a fine, even texture, straight grain, and clear yellow color. The principal uses are for specialty products, boats, interior trim, outdoor uses, and heavy construction—wherever durability, acid resistance, stability, smooth-wearing qualities, and workability are needed. Production has been low in the past, largely because the species is scattered and the cost of logging is high. But as logging for other species progresses to poorer sites and higher elevations, production is increasing. Efforts are being made to market lower grades, and domestic use is expanding. Much of the lumber and logs is now exported to Japan.

Arland Harris

Alaska-Cedar. A Bibliography With Abstracts, by A.S. Harris (9)

This bibliography contains references to North American and European literature containing information about Alaska-cedar. References are listed alphabetically by author, and abstracts are given for many of those considered more significant. A subject matter index is included, as is a list of scientific and common names of tree species.

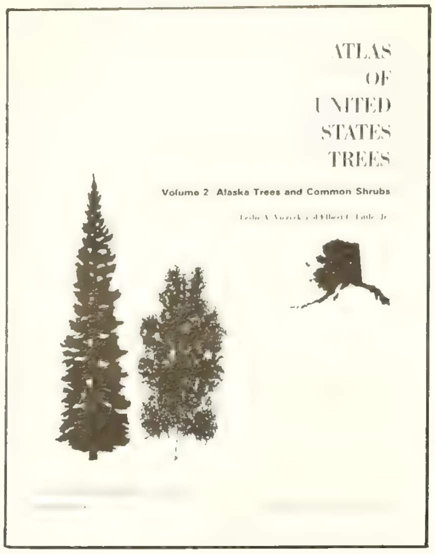
The compiler would appreciate learning of additional articles on Alaska-cedar not included here.

Cones and foliage of Alaska-cedar

Sitka Spruce—A Bibliography With Abstracts, by A.S. Harris and Robert H. Ruth (10)

This bibliography contains references to world literature on Sitka spruce published through 1967. A subject matter index and a list of scientific and common names of tree and plant species is included. References are listed alphabetically by author. Abstracts are given for many references.

Special effort was made to include the large body of British literature resulting from extensive plantings of Sitka spruce in the British Isles—an important source of information sometimes overlooked by American foresters.


ATLAS OF UNITED STATES TREES

Volume 2 Alaska Trees and Common Shrubs

Atlas of United States Trees, Volume 2. Alaska Trees and Common Shrubs, by Leslie A. Viereck and Elbert L. Little, Jr. (11)

This volume contains large maps showing the natural distribution or range of the native tree species of Alaska. The 82 species maps include 32 trees, 6 shrubs rarely reaching tree size, and 44 more common shrubs.

Twenty-three general maps summarize environmental factors and supply background information on geography, geology, climate, and vegetation. These basic maps indicate the broad conditions under which each species grows wild and may serve as a preliminary forest atlas of the 49th State.

environment, ecology

Alaska Ecosystem Featured

In 1974, the Experiment Station began a 10-part series of General Technical Reports on the forest ecosystem of southeast Alaska. The intent was to provide resource managers and users of southeast Alaska's forest resources with the most complete information available for estimating the consequences of various management alternatives.

The papers summarize published and unpublished reports and data as well as the observations of resource scientists and managers developed over years of experience in southeast Alaska. The reports serve as an aid in planning future research and as background information for land use planning in that region.

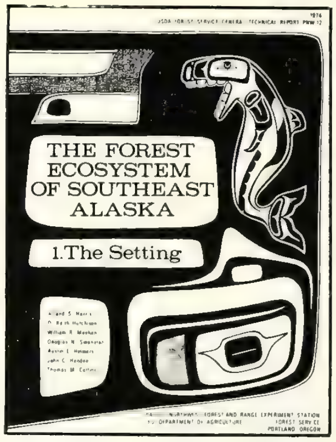
The Forest Ecosystem of Southeast Alaska, 1. The Setting, by Arland S. Harris and Others (12)

A description of the discovery and exploration of southeast Alaska sets the scene for a discussion of the physical and biological features of this region. Subjects discussed include geography, climate, vegetation types, geology, minerals, forest products, soils, fish, wildlife, water, recreation, and esthetic values.

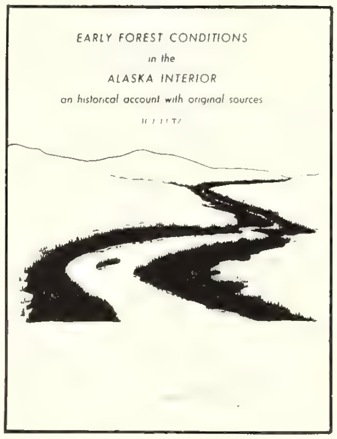
This is the first of a series of publications summarizing present knowledge of southeast Alaska's forest resources. Publications will follow which discuss in detail the subjects mentioned above and how this information can be helpful in managing the resources.

Other publications in this series include the following:

2. Forest Insects (13)
3. Fish Habitats (14)
4. Wildlife Habitats (15)
5. Soil Mass Movement (16)
6. Forest Diseases (17)
7. Forest Ecology and Timber Manag ment (18)
8. Water (19)
9. Timber Inventory, Harvesting, Marke ing, and Trends (20)
10. Recreation (in preparation/1976)


THE FOREST ECOSYSTEM OF SOUTHEAST ALASKA

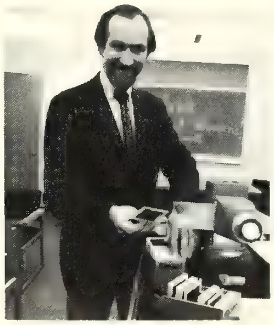
1.The Setting


EARLY FOREST CONDITIONS in the ALASKA INTERIOR an historical account with original sources

Early Forest Conditions in the Alaska Interior, by H.J. Lutz (21)

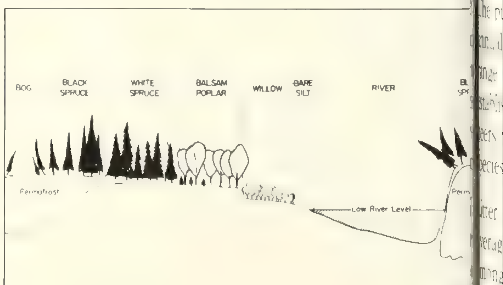
This report is based almost wholly on the journals, records, and publications of early observers of forest conditions in Alaska's interior. These observers generally had no special training in forestry or in matters pertaining to the productivity, growth, and yield of forests or stands of trees. They were explorers, geologists, army and navy officers, and a few natural scientists. Their observations on forest conditions were often incidental to other more central objectives and the care and accuracy used in arriving at their estimates and measurements can only be conjectured. Consequently, caution should be used when comparing present-day forests with those described by the early writers.

The historical record of early forest conditions in the Alaska interior, compiled from the original sources, is presented. The question, "What were the forest conditions in the early days?" has been answered as best it can.


Les Viereck

Forest Succession and Soil Develo ment Adjacent to the Chena River i Interior Alaska, by Leslie A. Vierec (22)

Changes in soil and vegetation were studie in four stands growing on different age river deposits on the flood plain of th Chena and compared with a climax stand o a higher and older terrace. The stands we a 15-year-old willow stand on a new formed gravel bar, a 50-year-old balsa poplar stand, a 120-year-old white spruc stand, a 220-year-old white spruce/blac spruce stand, and a climax black spruc sphagnum stand. The vegetation characte istics of each stand are given.

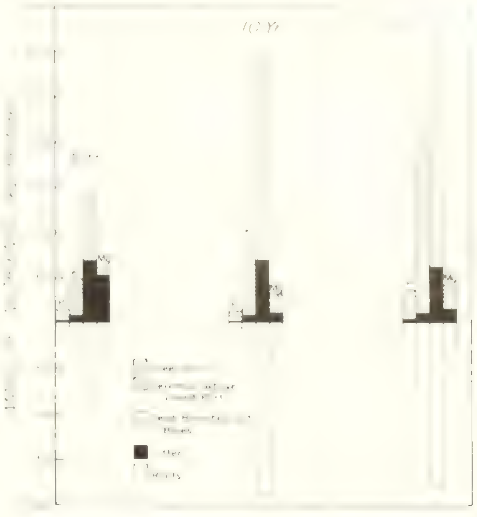


Diagrammatic cross section of typical distribution vegetation and permafrost across a meander of a riv in interior Alaska.

istribution of Selected Chemical Elements in Even-Aged Alder (*Alnus*) Ecosystems Near Fairbanks, Alaska, by Keith Van Cleve and Leslie A. Viereck (23)

he influence of vegetation with time on ie nutrient balance of even-aged alder ecoystems was demonstrated by the researchs. By analysis of selected nutrients (Ca, K, Ig, P, and Mn) in newly formed sand bars id in alder stands of 5, 15, and 20 years, was found that there were a number of gnificant changes in the distribution of iese elements within the ecosystem. In the il there was a general decrease in pH in ie older stands whereas cation exchange ipacity and soil organic matter showed eneral increases. These changes showed a close relationship to increases in percentage of organic matter. Exchangeable nutrients were lowest in the time zero soils, showed a marked increase in the 5-year stage, but showed no consistent further increase in the older stands. Their distribution was related to both texture and soil organic matter content.

In the ecosystem vegetation, the mass of nutrient elements was related to plant biomass and increased with ecosystem age. Ca showed the greatest mass at 20 years. Ranking of the nutrient mass was generally Ca > K > Mg > P > Mn. Alder contributed from 69.9 to 91.2 percent of the mass of ash for the 5- and 20-year stands respectively.



Mass of selected nutrient elements in components of alder ecosystems.

ummary of Climatic Data for the Bonanza Creek Experimental Forest, by Richard J. Barney and Erwin R. Berglund (24)

summary of climatic data during the 968-71 growing seasons is presented for he subarctic Bonanza Creek Experimental orest located near Fairbanks, Alaska. Data vere obtained from three weather station ites at elevations of 1,650, 1,150, and 550 eet from May until September each year. Data are for relative humidity, rainfall, and naximum, minimum, and mean temperaures. Analyses indicate that Fairbanks nean monthly temperatures were higher han those at Nenana or at the Bonanza Creek Experimental Forest.

nnual Tree-Litter Production by Successional Forest Stands, Juneau, Alaska, by Richard M. Hurd (25)

itter production from high latitude forests n North America is not well documented, nd even less is known about litter producion from successional forest stands within a elatively small area receiving essentially niform radiant energy input at such latiudes. An opportunity exists near Juneau to letermine litter production both for relatively igh latitude forest and for several succesional forest stands following the recession f the Mendenhall Glacier.

he purpose of this study was to determine nnual tree-litter production through a ange of successional stands from recently stablished, relatively ephemeral, woody pioeers to older, more permanent forest tree pecies.

itter production in four stands for 3 years veraged 2,850 kg/ha. Production varied mong stands and years, but no real differnces were apparent. Nonwoody litter was bout 64 percent of total litter and,alhough less variable, there were no conistent differences for stands or years.

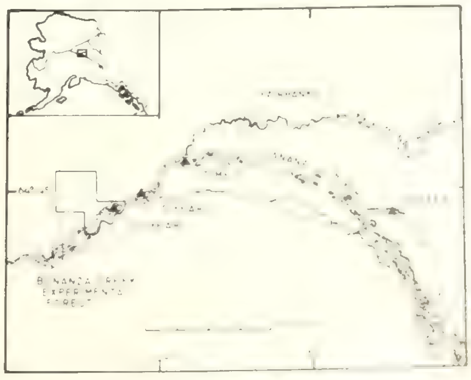
Accumulation of Nitrogen in Alder (*Alnus*) Ecosystems Near Fairbanks, Alaska, by Keith Van Cleve, Leslie A. Viereck, and Robert L. Schlentner (26)

Biomass and nitrogen accumulation was investigated in even-aged alder ecosystems on the Tanana River flood plain near Fairbanks. The distribution of biomass and nitrogen was recorded for foliage, branches, boles, roots, litter, and soil.

After a rapid increase in mean annual biomass increment during the first 5 years of ecosystem development, the increment showed a slower but steady increase from 5 through 20 years. The productivity of these ecosystems occupied an intermediate position compared with the productivity of forest ecosystems in other geographic regions.

The mean annual rate of nitrogen build-up was rapid during the first 5 years of ecosystem development but decreased with ecosystem age to 20 years.

Rates of addition of N in these alder ecosystems were equal to or greater than those reported for alder by other investigators. Periodic additions of N may occur by flooding and these additions are probably small compared with additions of N by symbiotic fixation.



Location of the study areas on Tanana River floodplain

Rainfall Interception by Mature Coniferous Forests of Southeast Alaska, by J.H. Patric (27)

Rainfall intercepted by the crowns of trees is wasted in the sense that it neither replenishes soil moisture nor streamflow. The author reported that southeast Alaska forests, like other mature coniferous forests of western North America, intercept about 25 percent of annual rainfall.

Scientist Patric points especially to western hemlock as a tree that is "waterproof." If you're ever caught in a southeast Alaska downpour, it would be wise to head for a mature stand of that species. The trunks of hemlock trees remained at least partly dry during weeks of continuous rain. Concentrations of rain shed from central "drip points" in the crowns of western hemlock, but there was little stemflow.

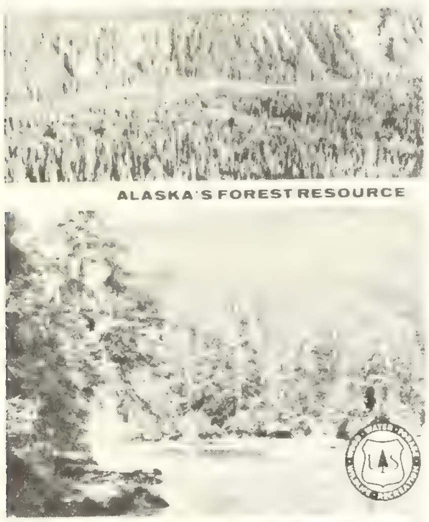
For forest managers, he also makes an observation about the effect of timber harvest on streamflow. Removing or reducing the forest canopy by logging would reduce but not eliminate interception loss and correspondingly increase streamflow. This method of increasing water yield has not yet been tested in southeast Alaska.

More on Subarctic Environments

A number of papers written by hydrologist Charles W. Slaughter before he joined the Forest Service research staff in Fairbanks may be of interest. His work prior to 1976 dealt primarily with snowpack management, the effects of roadbuilding on thaw and erosion, and climate in the subarctic. For information, write to Slaughter at the Institute of Northern Forestry in Fairbanks.

forest survey, volume tables, lumber grade yields

resource statistics

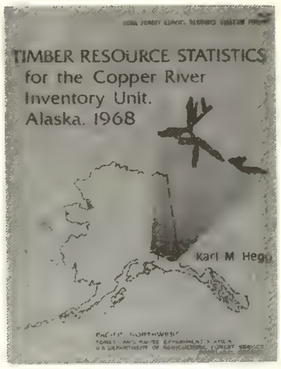

ALASKA'S FOREST RESOURCE

Alaska's Forest Resource, by O. Keith Hutchison (28)

This report presents the results of the first forest inventory of Alaska, made as part of the nationwide Forest Survey. Forest inventory work began in Alaska in 1954. Because of recognized regional economic and forest differences, the inventory was done in two parts—coastal and interior.

Alaska has 16 percent of the forest land in the United States, or 119 million acres. This is as much forest land as is found in the states of Montana, Washington, Oregon, and California combined. But the average quality of forest land in Alaska is below that of the other states mentioned. Only 28.2 million acres is considered commercial; that is, capable of producing a minimum of 20 cubic feet of industrial wood per acre annually. Oregon alone has nearly as many acres of commercial forest land.

Keith Hutchison


TIMBER RESOURCE STATISTICS
for the Copper River
Inventory Unit.
Alaska. 1968

Karl M Hegg

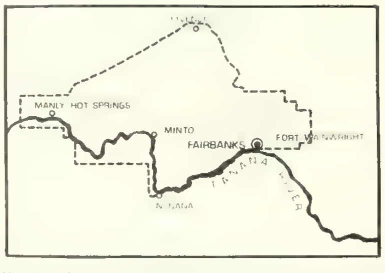
Timber Resource Statistics for the Copper River Inventory Unit, Alaska, 1968, by Karl M. Hegg (29)

This first intensive forest inventory of Alaska's Copper River Valley found a commercial forest area of 287,800 acres with 303.8 million cubic feet of growing stock. In addition, a noncommercial stratum was examined that had substantial standing volume but did not meet the growth criteria for commercial forest land. This stratum contained 152,800 acres with a volume of 157.9 million cubic feet. Because of the distance from population centers and the general low quality of the timber, the Copper River stands probably would be marginal suppliers to the world market.

Karl Hegg

Timber Resource Statistics for the Fairbanks Block, Tanana Inventory Unit, Alaska, 1970, by Karl M. Hegg (30)

This report for the 3-million-acre Fairbanks block is the first of four on the 14-million-acre Tanana Valley inventory unit. Observations are made on forest condition, defect, stand regeneration, fire history, and present use. Data are provided for an operable noncommercial forest land category as well as for standard Forest Survey area and volume statistics. Commercial forest land occupies three-quarters of a million acres and has a net volume of 578 million cubic feet. Growing-stock volume on 51,000 acres of operable noncommercial forest land is 49.6 million cubic feet.

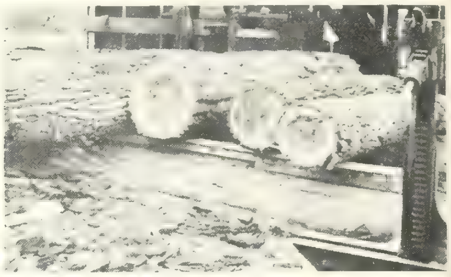


The Fairbanks block of the Tanana Valley inventory unit

Forest Resources of the Susitna Valley, Alaska, by Karl M. Hegg (31)

This report summarizes the data from the first intensive inventory of the forests in the Susitna Valley, Alaska, conducted during the period 1964-65.

Approximately 5.6 million acres were included in the inventory. Of this, forests cover about 3.2 million acres, with commercial stands making up nearly 1.3 million acres. The principal species are paper birch, which occupies 64 percent of the commercial forest area; spruce, 26 percent; balsam poplar-cottonwood, 9 percent; and aspen, 1 percent. The net volume in growing-stock trees is 1.4 billion cubic feet or 4.1 billion board feet. Growth rates are low—total net annual growth is only 2.2 percent of net volume but averages 25 cubic feet per acre per year.


Grades 1 and 2 cottonwood logs at a small sawmill in the Matanuska Valley.

Forest Statistics for the Upper Koyukuk River, Alaska, 1971, by Karl M. Hegg (32)

Area and volume statistics from the first intensive forest inventory of the upper Koyukuk River drainage, in north-central Alaska, are given. Observations are made on forest location, description, defect, regeneration, growth, and mortality. Commercial forests, although generally restricted to a narrow band along drainages, were found as far as 70 miles (113 kilometers) north of the Arctic Circle. Commercial forests occupy less than 5 percent of the 742,000-acre inventory area but, despite the northerly latitudes, support an average volume in excess of 1,100 cubic feet per acre (80 cubic meters per hectare).

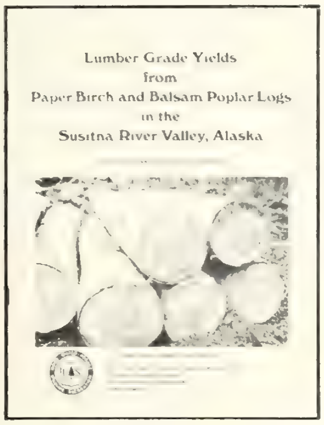
Areas of Nonforest and Noncommercial Forest Lands by Cover Type and by Topographic Site for Interior Alaska, by Karl M. Hegg and Ronald M. Dippold (33)

Previously unreported land-cover data obtained during a 1957-62 forest inventory of 229 million acres of interior Alaska are given. Tables have been prepared for 10 subunit divisions showing area of noncommercial land by topographic site and nonforest land by eight different ecosystems. A brief description is given of methodology and terminology.

growth and yield

Growth and Yield of Well-Stocked Aspen and Birch Stands in Alaska, by Robert A. Gregory and Paul M. Haack (34)

Presents normal yield tables for well-stocked, even-aged stands of quaking aspen and paper birch in interior Alaska.


Lumber Grade Yields
from
Paper Birch and Balsam Poplar Logs
in the
Susitna River Valley, Alaska

Lumber Grade Yields From Paper Birch and Balsam Poplar Logs in the Susitna River Valley, Alaska, by Leland F. Hanks and Carl W. Swanson (35)

A study was conducted at Wasilla, Alaska, in 1964 to determine the lumber grade recovery from paper birch and balsam poplar logs. Actual recoveries are summarized by scaling diameter for each of the three U.S. Forest Service log grades. This information, when coupled with pertinent lumber prices, may be used to estimate the value of lumber to be sawn from birch or poplar logs in Alaska.

The Susitna River Valley.

Lumber Yield From Sitka Spruce in Southeastern Alaska, by Paul H. Lane, Richard O. Woodfin, Jr., John W. Henley, and Marlin E. Plank (36)

About 98 percent of the Sitka spruce lumber sawn in a southeastern Alaska lumber recovery study was in cants 3 to 8 inches in thickness. Thirteen percent of the lumber volume was graded No. 2 and 3 Clear by the Pacific Lumber Inspection Bureau rules and 9 percent Piano under Export rules.

Study cants being graded and tallied on green chain.

Growth and Yield of Well-Stocked White Spruce Stands in Alaska, by Wilbur A. Farr (37)

Site index curves and normal yield tables are presented for even-aged stands of white spruce in interior Alaska. Site is based on height of the four tallest trees per acre at index age 100 years. Yields are related to combinations of the variables, site index and age.

Wilbur Farr

volume tables

Volume tables have been developed for most of the major tree species in Alaska. The following reports are available:

- Western Redcedar and Alaska-cedar in Southeast Alaska (38)
- Western Hemlock and Sitka Spruce in Southeast Alaska (39)
- White Spruce, Balsam Poplar, and Paper Birch of the Kuskokwim River Valley (40)
- White Spruce in Interior Alaska (41)
- Aerial Photo Volume Tables for Interior Alaska Tree Species (42)
- Western Hemlock in Southeast Alaska—Utilization, Lumber Recovery, and Chip Yield (43)

measurement techniques

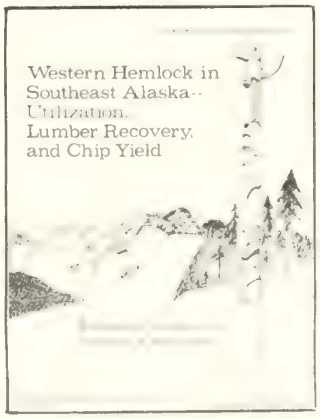
Using Aerial Photographs

When the initial survey of forest resources of interior Alaska was begun in 1956, it was apparent that the usual inventory technique, using complete photo coverage with a large ground sample, would be too costly. The country was just too vast. The survey area encompassed 229 million acres.

This paper describes a "triple sampling" design that was selected for the inventory. See *A Photo Identification Guide for the Land and Forest Types of Interior Alaska,* by Karl M. Hegg (44)

A Cull Estimation Method for Use in Forest Inventory and Timber Sale Cruises, by Vernon J. LaBau and Thomas H. Laurent (45)

This report summarizes a study of cull in standing trees in the old-growth hemlock spruce forests of southeast Alaska. Results provide improved techniques for predicting cull in standing Sitka spruce and western hemlock.


Western Hemlock in
Southeast Alaska--
Utilization,
Lumber Recovery,
and Chip Yield

Western Hemlock in Southeast Alaska—Utilization, Lumber Recovery, and Chip Yield, by R.O. Woodfin, Jr., and T.A. Snellgrove (43)

This report presents lumber recovery information on a sample of western hemlock trees selected from southeast Alaska national forest land and sawed at a southeast Alaska mill cutting for the Japan export market. Data discussed includes cubic volume yields, cull log lumber recovery, estimates of chippable wood, and logging residue from sample trees.

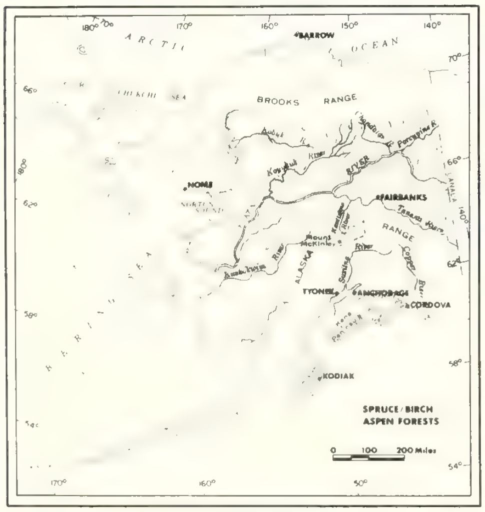
timber management

interior alaska

silviculture

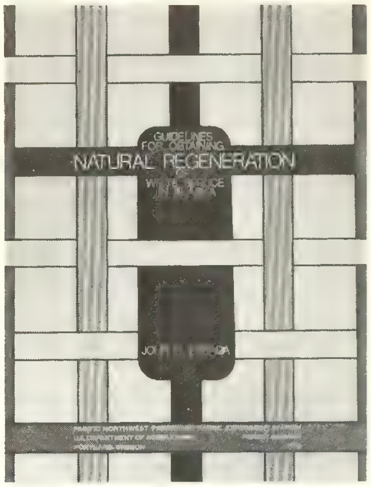
Ecological and Silvicultural Considerations, Alaska's Interior Forests, by John C. Zasada (46)

In climate, physical geography, species composition, and other properties, Alaska's interior forests are similar to those found in the northern United States, Canada, Finland, Norway, and Sweden. Productivity is adequate for forestry to be considered a legitimate land use, and current research indicates that stands can be regenerated. The author suggests that silvicultural practices developed in other northern forests should be evaluated to determine their applicability in the taiga.



Timber Resources and Utilization, Alaska's Interior Forests, by O. Keith Hutchison and David R. Schumann (47)

Interior Alaska has about 105.8 million acres of forest land, of which 22.5 million acres is estimated to have potential commercial value. These 22.5 million acres contain a total growing stock of 14.25 billion cubic feet of white spruce, paper birch, quaking aspen, and balsam poplar. The potential of the interior forests compares favorably with that of the Lake States, where stands in Minnesota average 574 cubic feet per acre as compared to 634 cubic feet per acre in interior Alaska. About 50 small sawmills now operate to supply local markets plus some beginning export of chips and cants.


GUIDELINES
FOR OBTAINING
NATURAL REGENERATION

Guidelines for Obtaining Natural Regeneration of White Spruce in Alaska, by John C. Zasada (48)

These guidelines are based on research conducted in western white spruce forests of Canada and minimal Alaskan observations and research. The author reviews basic requirements for natural regeneration of white spruce and recommends methods for creating conditions which meet these requirements. Survey techniques are summarized for determining adequacy of seedbed preparation and regeneration.

Response of 70-Year-Old White Spruce to Thinning and Fertilization in Interior Alaska, by Keith Van Cleve and John C. Zasada (49)

Forest thinning and fertilization are important management techniques for increasing forest productivity. This paper reports the results of the first 5 years of a study designed to assess the effects of thinning and fertilization on the growth of a 70-year-old white spruce forest in interior Alaska on the Yukon-Tanana uplands 33 km west of Fairbanks.

Basal areas of the trees were measured as to their response to fertilization, thinning, thinning plus fertilization, and compared to a control. A significant increase in basal area increment over the control was produced during each of the five growing seasons in both the thinned and thinned + fertilized treatments. During this period, the thinned + fertilized treatment consistently produced the greatest basal area increment.

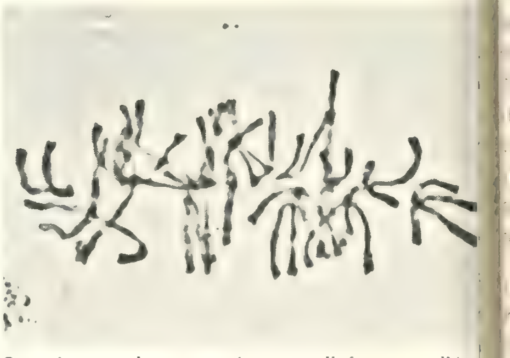
John Zasada

Natural Regeneration of Interior Alaska Forests—Seed, Seedbed, and Vegetative Reproduction Considerations, by John C. Zasada (50)

The forests of interior Alaska are a complex mosaic of stands which are related to their fire history. Following fire, the major interior forest tree species—white spruce, black spruce, paper birch, quaking aspen, and balsam poplar—can regenerate from seed and/or by vegetative means. The author discusses various aspects of seed production (including seedbed considerations) and vegetative reproduction as they may relate to burn reforestation.

Albino Seedlings of White Spruce, by John C. Zasada and Lawson L. Winton (51)

The researchers described their studies on seeds collected from a stand of mature white spruce trees (*Picea glauca* [Moench] Voss) which produced almost 2 percent albino seedlings. None of the albinos lived more than a few weeks, and all had normal chromosome counts of $2n = 24$. Chlorophyll deficiency is evidently a recessive character, but observation did not resolve current questions of whether the character is controlled by one or more genes or is linked with an embryonic lethal. The authors feel that the albino seedlings may have resulted from self-fertilization of one or more parent trees.


*Somatic metaphase stage in one cell from an albino white spruce seedling, with 2*n*=24 chromosomes.*

White Spruce Cone and Seed Production in Interior Alaska, 1957-68, by John C. Zasada and Leslie A. Viereck (52)

Observations indicate that very good seed years may be separated by at least 10 to 12 years, although during this interval individual stands may produce from one to several fair or good cone crops.

The authors discuss estimates of seedfall per acre, seed dispersal over time, cone production by individual trees, number of seeds per cone and per tree, and cone crop rating from white spruce stands in interior Alaska for the period 1957-68.

Paper Birch Seed Production in the Tanana Valley, Alaska, by John C. Zasada and Robert A. Gregory (53)

The paper birch (*Betula papyrifera*) forest type covers over 5 million acres of Alaska, and many of these stands originated from seed following destruction of the previous stands by fire. Information on seed production characteristics of this species enhances our knowledge of its natural regeneration. The authors report their results of a study of the quantity and quality of paper birch seed crops.

The authors suggest that seed crops adequate for natural regeneration of 100-foot-wide clearcuts occur in at least 1 out of every 4 years in this portion of the taiga.

Seed traps: A, Thimble trap in place (surface area, 0.041 square meter); B, funnel trap in place (surface area, 0.050 square meter).

The Effect of Temperature and Stratification on Germination in Selected Members of the Salicaceae in Interior Alaska, by John C. Zasada and Leslie A. Viereck (54)

In Alaska, seeds of salicaceae can be divided into two general groups, those dispersed in spring and early summer and those dispersed in September and October.

On tests of five species, the seed of four early-seeding species germinated completely at temperatures of 25, 20, 15, 10, and 5° C. The seed of one late-seeding species germinated completely only after stratification and then only at 25, 20, and 15° C.

Effect of Cone Storage Method and Collection Date on Alaskan White Spruce (*Picae glauca*) Seed Quality, by John C. Zasada (55)

White spruce cone storage and time of collection significantly affect germination. The author and colleagues investigated aspects of the effect of various approaches to storage and collection on white spruce seed quality. The effects of collection date and method of cone storage were investigated for Alaskan spruce seeds.

The results on germination tests are considered with respect to specific gravity and percent moisture content changes in the cones and embryo growth.

Aspen Root Suckering in Alaska: Effect of Clone, Collection Date, and Temperature, by John C. Zasada and George A. Schier (56)

Many of the aspen (*Populus tremuloides* Michx.) stands in Alaska originated from root suckers after the parent stands were destroyed by fire. Although there has been extensive research in other parts of the species' range on the capacity for aspen to sucker, there has been no research conducted on Alaskan genotypes. To obtain this basic information, the authors examined initial sucker development on excised roots from three Alaskan clones as affected by date of collection, clone, and temperature.

miscellaneous

Frost Damage to White Spruce Cones in Interior Alaska, by John C. Zasada (57)

During studies of seed production in 1969 in interior Alaska, an exceptionally warm April and May followed by a relatively mild late-May frost permitted the observation of some effects of freezing temperatures on cone and seed production. Although this subarctic region is characterized by a relatively cold climate, this was the first observation of frost damage to white spruce cone and seed crops.

Variability in frost damage to white spruce cones. A—dead cone; N—apparently undamaged cone; other cones have variable number of damaged scales.

Cambial Activity in Alaskan White Spruce, by Robert A. Gregory

There is now considerable evidence that the rate of growth in diameter of trees is closely associated with circumferential growth of the vascular cambium. The author discusses his work on cambial activity in stems of Alaskan white spruce, *Picea glauca*. The objective of this study was to record natural cytological (cell) events and anatomical features associated with secondary growth of tree stems. This is an essential step preceding a search for mechanisms promoting tree growth.

History of Sitka Spruce Planted in 1805 at Unalaska Island by the Russians, by H. J. Lutz (59)

Over 150 years ago Sitka spruce trees were planted by the Russians on naturally treeless Unalaska Island. This was perhaps the first attempt at afforestation on the North American continent. All the Aleutian Islands are treeless; the western limit of natural tree growth on the Alaska Peninsula occurs roughly between Naknek Lake and Becharof Lake at the base of the peninsula. The author reviews the history of the spruce on Unalaska Island and summarizes the literature of other writers who have studied the question of why the Aleutian Islands and the westward portion of the Alaska Peninsula are treeless.

Severe winds and unfavorably low temperatures during the growing season are the climatic elements most commonly regarded as limiting factors. Other authors suggest that the absence of trees is to be explained by the newness of the land areas involved and their isolation from sources of tree seed. In other words, sufficient time has not elapsed for trees to reach the westward parts of the Alaska Peninsula and the Aleutian Islands. In support of this view is the fact that trees are now advancing into previously treeless areas on the Alaska Peninsula and on Kodiak Island.

southeast alaska

silviculture

Natural Reforestation on a Mile-Square Clearcut in Southeast Alaska, by A.S. Harris (60)

After clearcutting, the forest cover must be established promptly to restore the landscape's natural beauty, to minimize erosion, and to assure a sustained yield of timber. Natural regeneration requires little or no investment and so is preferable if the resulting stands compare favorably with those originating under artificial methods.

A study of natural regeneration began in 1954 on the Maybeso Experimental Forest near Hollis, Prince of Wales Island, Alaska. One cutting unit, referred to as the "mile-square" unit, was made especially large to determine distance of seed dispersal. Eight growing seasons after logging began, the mile-square cutting unit, as a whole, was well stocked, as shown by a regeneration survey. However, it was apparent that stocking was far from uniform, with some small areas occupied by dense thickets of spruce and hemlock and others sparsely stocked.

SEED YEAR	AVERAGE SEEDS PER TRAP (6 square feet)	SPECIES COMPOSITION		
		Hemlock	Spruce	Cedar
	Number		*Percent*	
1956-57[1]	10.8	37	38	25
1957-58	13.8	95	3	2
1958-59	1.9	48	37	15
1959-60	40.8	39	46	15
1960-61	1.8	28	57	15
1961-62	.2	89	11	0

[1] Incomplete data—include counts only until January 20, 1957

Average annual seed catch since logging; mile-square cutting unit, Maybeso Experimental Forest.

Clearcutting, Reforestation and Stand Development on Alaska's Tongass National Forest, by A.S. Harris (61)

Clearcutting appears to be the most desirable silvicultural system for use on the Tongass to secure good natural stocking and rapid growth of conifer regeneration. Increased soil temperature improves nutrient cycling, and added light encourages Sitka spruce, a relatively shade-intolerant species. It is also a desirable system for use in stands infested with hemlock dwarf mistletoe.

Continued reliance on natural reforestation is anticipated, with increasing use of planting to supplement natural reforestation on difficult sites. Clearcutting is likely to continue as the predominant silvicultural system, but other systems may be useful in situations where clearcutting is incompatible with other resource values.

Alaska State Ferry approaching the dock at Sitka. Old-growth timber in the background was clearcut four years earlier.

What Happens to Nonmerchantable Trees Left After Clearcutting? by Robert S. Embry (62)

This study of western hemlock and Sitka spruce left standing after clearcutting shows a 5-year survival rate of 51 percent. Wind and logging damage caused greatest mortality. Response of diameter growth was good but height growth response was poor. The trees produced cones but the quality of the seed was not determined.

It seems unlikely that residual trees such as those reported upon will form a significant part of a new stand or be detrimental to its establishment. They may, in some cases, serve as a supplementary seed source on cutover areas. The genetic quality of this seed is not known, but so far, the author reasons, there is no reason to suspect that seed produced by these trees is genetically inferior. He concludes that there appears to be no silvicultural reason for eliminating residual trees in this and comparable situations.

Natural Reforestation After Logging on Afognak Island, by A.S. Harris (63)

Sitka spruce is the only conifer on Afognak Island, Alaska. Observations of natural reforestation on a 100-acre cutting unit on the island 25 years after logging showed that some areas were still dominated by grass-herbaceous vegetation and that growth of Sitka spruce seedlings was slow. This competition probably is slowing growth of trees and preventing natural restocking of spruce. If such conditions prove to be typical, measures to control competition will be necessary to insure adequate reforestation after logging on Afognak Island.

Many spruce seedlings such as this one at Kazakof Bay are growing slowly. The observer is standing in dense fireweed-grass-salmonberry cover that offers severe competition for Sitka spruce.

Effects of Slash Burning on Conifer Regeneration in Southeast Alaska, by A.S. Harris (64)

A test was made at Kina Cove, Prince of Wales Island, to determine if slash burning would improve seedling distribution by providing a more uniform seedbed, and favor Sitka spruce, a highly desirable species.

It was found that fewer seedlings became established on the burn, but stocking percent was higher, showing that the seedlings present were better distributed. The percentage of spruce was higher on the burn. The reason for the improved response of spruce on burned plots is not known, although it appeared to be related to improved conditions for initial spruce seedling establishment, rather than improved survival under the burned conditions.

Partial Cutting of Western Hemlock and Sitka Spruce in Southeast Alaska, by Wilbur A. Farr and A.S. Harris (65)

This study of response of western hemlock and Sitka spruce to partial cutting over a 17-year period in a 96-year-old stand at Karta Bay, Alaska, showed that crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning, but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

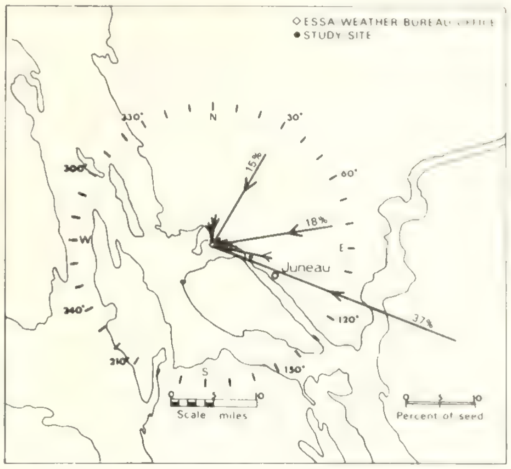
Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots became well stocked with conifer regeneration, mostly western hemlock.

One-half-acre plot thinned to two-thirds of basal area in 1950, as it appeared in 1967.

Ripening and Dispersal of a Bumper Western Hemlock-Sitka Spruce Seed Crop in Southeast Alaska, by A.S. Harris (66)

Both hemlock and spruce are prolific seed producers. During the heavy seed year of 1966-67, a mature western hemlock-Sitka spruce stand produced an average of 131 pounds of seed per acre, 23 percent of which was sound.

Seed was dispersed over a 1-year period beginning on October 22, with cone scales opening and closing in response to moisture, and seedfall increased by wind. Information on cone condition, seed ripening, and weather conditions associated with seed dispersal is given in the report.



Percentage of seed dispersed on days with prevailing wind direction indicated (length of vector line indicates percentage of seed dispersed). Juneau, Alaska, 1966-67.

Mechanics of Debris Avalanching in Shallow Till Soils of Southeast Alaska, by Douglas N. Swanston (70)

Excessive slope gradient and pore-water stress in glacial till soils of the Karta series have been found to be primary factors in debris avalanche and flow occurrence in recently logged areas of southeast Alaska.

The author reports on the applicability of standard soil mechanics techniques to evaluation of factors affecting debris avalanching in the steep, shallow, permeable till soils. He also quantifies relationships between these factors which, up to now, have only been suggested on the basis of field observations.

Environmental effects

Mass Wasting in Coastal Alaska, by Douglas N. Swanston (67)

An understanding of erosion processes involving downslope movement of earth materials is essential to the forest-land manager in Alaska. This had become increasingly clear in recent years with the apparent acceleration of slope erosion following large-scale clearcutting of steep, timbered slopes in southeast Alaska. Erosion occurs primarily as soil mass movements associated with oversteepened slopes and high soil-water levels.

This paper summarizes and interprets the accumulated data and knowledge about slope erosion in southeast Alaska, particularly in relation to recently logged areas, with general suggestions and guidelines for prediction and control.

Landslides on Logged Areas in Southeast Alaska, by Daniel M. Bishop and Mervin E. Stevens (68)

Recent large-scale clearcut logging of timber in southeast Alaska has accelerated debris avalanches and flows on steep slopes during heavy rainfall. The authors present information on the general mechanics of landslides and how they relate to slides in southeast Alaska. They discuss factors influencing shear stress, such as earthquakes, tilting, precipitation, vegetation, and construction. They discuss factors influencing shear strength, such as parent materials, pore water, weight, root deterioration, and construction projects. The authors also present a review of literature on slides in timbered areas through discussion of the work of researchers in New Hampshire, Oregon, Japan, and Italy.

Judging Landslide Potential in Glaciated Valleys of Southeast Alaska, by Douglas N. Swanston (69)

The author presents a very interesting first-person narrative account of a reconnaissance he conducted with colleagues on slide-prone areas of southeast Alaska. They studied and recorded slope stability characteristics of several areas, and developed accurate techniques for stability mapping.

The author concludes from his studies that, in terms of good land management policy, areas within highly unstable zones should be entirely withdrawn from developmental activities. Any disruption of surface cover or disturbance of the soil mantle in such areas is almost certain to cause or accelerate landslide occurrence, with little chance of effective control. Areas in the potentially unstable zone should be examined carefully for evidence of unstable conditions on a local basis, and operation and development criteria should be designed to fit each stability situation encountered.

A surface view of a landslide showing some of the important characteristics determining stability. Parent material is a glacially smoothed granite covered with less than 12 inches of soil. Slope at point of failure is approximately 40°.

miscellaneous

Experience With Douglas-fir in Southeast Alaska, by A.S. Harris (71)

Douglas-fir does not occur naturally in Alaska, and there is no known fossil evidence to show that it has occurred in the state since the Pleistocene. However, under present climatic conditions, the species is capable of germinating, becoming established, making excellent growth, and producing viable seed far north of its present northern coastal natural limit. Observations from Alaska are only fragmentary and of short duration, but the excellent growth reported suggests that Douglas-fir may be of future silvicultural value in Alaska.

Studies show that there may be a place for Douglas-fir in forest management in coastal Alaska when more intensive silviculture is practiced. However, widespread planting should be preceded by test plantings of a collection of provenances or progeny of individual parents. Such care will help in avoiding serious mistakes which could be made in the introduction of a new species.

The Economics of Rafting vs. Barging as Means of Transporting Logs in Southeast Alaska Waters, by Kenneth E. Beil (72)

Water transport of logs is the only possible method of transportation in the island geography of southeast Alaska. Logs have customarily been floated in rafts from producing points to water storage areas and to mills. A very limited amount of barging has taken place in Alaska, but a considerable amount takes place in coastal British Columbia.

The author examines two main questions relating to the economics of rafting and barging of logs: (a) Is it more economical for the timber producer to transport logs by barging or rafting in southeast Alaska waters? (b) What costs of barging and rafting are external to the timber producer and are they sufficient to warrant the use of one system or the other?

He concludes that there appears to be no compelling environmental reason to favor land-to-land barging over rafting if careful handling methods are followed, but there are very compelling economic reasons to favor rafting over barging.

Forest Residues in Hemlock-Spruce Forests of the Pacific Northwest and Alaska—A State-of-Knowledge Review With Recommendations for Residue Management, by Robert H. Ruth and A.S. Harris (73)

This report provides a detailed look at residue management throughout the north Pacific coastal fog belt, including Oregon, Washington, British Columbia, and Alaska. The approach is a general look at forest residues as part of the ecosystem, then a closer look at dead and decaying material after logging, considering fire hazard and the silvicultural, physical, chemical, and esthetic effects of this material. Residue treatments are described, evaluated, and recommended. The report is intended to provide an improved scientific framework for management decisions.

Small [illegible] chips, twigs, and needles [illegible] and rearing stream [illegible] life.

Specific Gravity of Western Hemlock and Sitka Spruce in Southeast Alaska, by Wilbur A. Farr (74)

Specific gravity is recognized as a simple, reliable index of wood quality. It is associated with many important strength and working properties of wood and is an indicator of pulp yields and wood weight. Because of its importance, the subject of specific gravity has received considerable attention.

In a recent growth and yield study of even-aged stands of western hemlock and Sitka spruce in southeast Alaska, trees of average basal area were felled and sectioned for stem analysis. The study provided the opportunity to collect specific gravity information with little additional effort. Results of an analysis of this specific gravity data are presented and discussed.

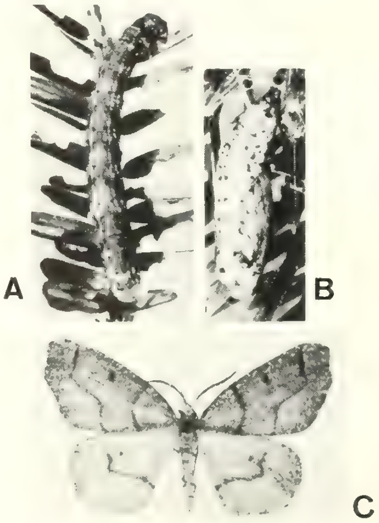
insect pests

general

Identification of Destructive Alaska Forest Insects, by J.S. Hard (75)

A guide to the identification of the principal forest insect enemies of Alaska's forests, including the defoliators and bark and stem borers. Information is given on life history and the type of damage each insect causes, and the importance of the pest. Keys, photographs, and illustrations will help in identifying the pest. Information about pest control is not given.

Identificaton of the offending pest may not always be possible with this guide. When significant damage to forest trees cannot be positively identified, samples of the damage and the insect should be collected and sent to Juneau for identification.



The western hemlock looper, Lambdina fiscellaria lugubrosa; *A. Mature larva, about one and one-fourth inch long; B. Mottled pupa, about five-eights inch long; C. Moth, wingspread about one and three-eighths inches.*

New Parasite-Host Records for North American Ichneumonidae (Hymenoptera) in Alaska, by Torolf R. Torgersen (76)

Twenty new parasite-host records for 16 North American species of Ichneumonidae are given. Hosts were collected in southeastern and interior Alaska.

Instructions for the Collection and Identification of Forest Insect Pests of Alaska and Their Parasites and Predators, by Richard A. Werner (77)

These instructions serve as an aid to entomologists in collecting and identifying forest insects of Alaska. It serves as a field guide in collecting insects and as a laboratory guide in rearing, preserving, and identifying insects.

interior alaska

Key to Adult Bark Beetles of White Spruce Stands in Interior Alaska, by Roy C. Beckwith (78)

With this key, entomologists can identify the adult Scolytidae (bark beetles) commonly found in white spruce stands in interior Alaska, including the Kenai Peninsula. Schematic drawings are included.

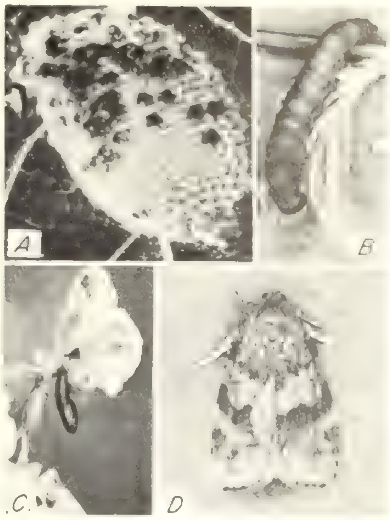
Scolytid Flight in White Spruce Stands in Alaska, by Roy C. Beckwith (79)

In white spruce stands near Fairbanks, Alaska, and on the Kenai Peninsula, Alaska, *Dendroctonus rufipennis, Ips* spp., and *Trypodendron lineatum* disperse in late May and early June. Other scolytids fly in June and July. Flight in interior Alaska is about 2 weeks earlier than on the Kenai Peninsula. Mean daily temperatures during spring and early summer are generally warmer in the interior than in coastal areas. There was a large increase in the total number of beetles in a thinned area, mostly of *Dryocoetes affaber.*

The Large Aspen Tortrix, by Roy C. Beckwith (80)

The large aspen tortrix (*Choristoneura conflictana*) periodically causes extensive defoliation throughout parts of the range of its principal host, the quaking aspen. The tortrix becomes a problem only where quaking aspen is a major part of the forest stand.

The author reviews current knowledge of the tortrix and presents information on its description, host trees, life history, and natural control factors. Artificial control of this species is not generally recommended except in high-use areas such as campgrounds because populations characteristically collapse in 2 or 3 years. Despite growth loss, aspen trees usually withstand the outbreak with little tree mortality.



Life stages of the large aspen tortrix: A, Egg mass—the black eggs are parasitized by Trichogramma minutum *and the white "eggs" are empty chorions following eclosion; B, mature larva; C, pupa; D, adult.*

White Spruce Seed Loss Caused by Insects in Interior Alaska, by R.A. Werner (83)

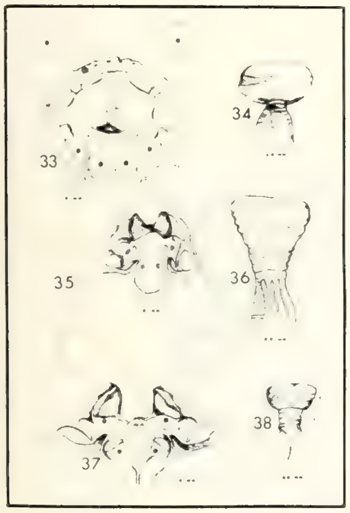
Several species of cone and seed insects were found to damage white spruce cones and seeds in interior Alaska. The insects caused serious damage to cones and seeds during 1 of the 5 years of this study. A new seed and cone insect, *Pegohylemyia* sp., was recorded for the first time from Alaska.

Insects damaged 3-6 percent of the seeds per cone during 4 of the 5 years of the study. In 1962, damage increased to 50 percent and most of it was caused by *Pegohylemyia* sp. Both cone and seed damage was least in 1958 when there was an abundant cone crop and the number of seeds per cone was high. In contrast, the greatest insect damage was in 1962 when few cones were produced but the number of seeds per cone was high. Insect damage to cones varied from 15 to 89 percent during the 5-year period.

Torgy Torgersen

Parasitoids Associated With the Large Aspen Tortrix in Interior Alaska, by Torolf R. Torgersen and Roy C. Beckwith (81)

Twenty-four species of parasitoids are associated with the large aspen tortrix in interior Alaska. Keys are supplied for determining adults and, in the absence of adults, the parasitoids based on host stage and on late-instar larval remains. Brief biological and descriptive notes are given for each species.



Final-instar cephalic structures and spiracles of hymenopterous larvae.
33, 34, Coccygomimus pedalis; *35, 36,* Phytodietus vulgaris; *37, 38,* Glypta inversa.

Skeeter Werner

Sex Identification of Adults and Pupae of a Birch Defoliator, *Rheumaptera hastata*, in Interior Alaska, by Richard A. Werner (82)

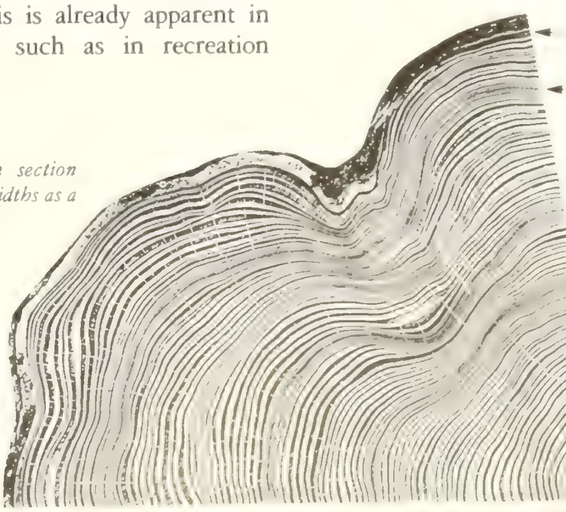
Populations of the spear-marked black moth, *Rheumaptera hastata* (L.), have reached epidemic levels in birch forests of interior Alaska in 1974 and 1975. Investigation of the life cycle and reproductive behavior could not be accomplished accurately without some method of differentiating the sexes. This paper describes a method for identifying sex in both pupae and adults.

southeast alaska

Field and Laboratory Techniques for Evaluating Hemlock Sawfly Infestations, by John S. Hard and Torolf R. Torgersen (84)

The hemlock sawfly causes much defoliation of western hemlock in localized areas in southeastern Alaska. As the intensity of forest resource management increases, there will be increasing demands on forest pest management specialists to assess the course of infestations. This is already apparent in high value stands such as in recreation areas, near population centers, and in high-risk, overmature stands.

This paper discusses techniques that will permit pest management personnel to determine trends in sawfly populations. Procedures are given for sampling and handling all stages of the sawfly. Methods are also shown for determining larval instar composition, survival, sex ratio, fecundity, and classes of mortality. Figures, descriptions, and a key are given to help the user diagnose and identify specific sources of mortality.

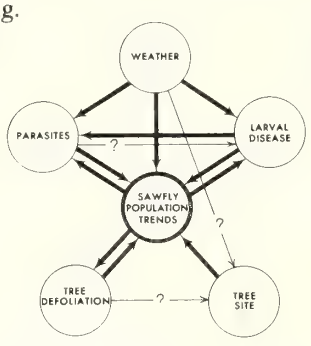


Western hemlock stem section showing reduced ring widths as a result of defoliation.

Natural Control of Hemlock Sawfly in Southeast Alaska, by John S. Hard (85)

Hemlock sawfly infestations occur most commonly in the warm southern half of southeast Alaska. Biotic factors that limit sawfly populations are a fungus which kills large numbers of female larvae, food quality as affected by host site and defoliation, and three ichneumonid parasitoid species which attack prepupal larvae in cocoons. The fungus was the most effective natural control in recent years, especially during wetter than normal summers. Parasites which attack after the fungus has decimated larval populations were most abundant during two dry summers. Parasitization and sawfly emergence were directly related, and both were highly inversely correlated with percentage fungus killed sawflies. Sawflies reared on lightly defoliated trees produced significantly more eggs than those reared on heavily defoliated trees, and fecundity was directly related to cumulative heat units during the summer.

Between 1952 and 1974, most negative sawfly population trends south of Frederick Sound occurred when two wet summers occurred consecutively. Apparent widespread collapse of sawfly populations in 1974 was associated with low temperatures in 1973 which delayed sawfly development and reduced opportunities for successful breeding.



Interaction of natural controls and hemlock sawfly populations in southeast Alaska. Broad arrows represent major relationships. Thin arrows with question marks represent minor suspected but undetermined relationships.

Parasites of the Western Hemlock Looper in Southeast Alaska, by Torolf R. Torgersen (86)

The western hemlock looper was found in Alaska for the first time in 1965. Field collections and laboratory rearings were conducted during 1966 to obtain life history data and to determine parasitization. Shortly after the completion of the 1966 field season, a salvage logging operation was carried out within and adjacent to the looper infestation. This permitted only a single season of fieldwork. Results of the preliminary studies dealing with the biology of the looper were reported by Torgersen and Baker.

This is a key to help entomologists identify parasites of the western hemlock looper. Eight major species of parasites are included in this first examination of the natural enemies of this looper in Alaska.

Budworm in Coastal Alaska, by John S. Hard (87)

Periodic outbreaks of black-headed budworms have been reported in southeast Alaska and on Prince William Sound since 1917. An outbreak in the 1950's caused severe defoliation of mature hemlock. Almost one-third of net volume was lost in some stands. The defoliation trend—ratio of acres defoliated in a given year to acres defoliated the year before—was directly related to regional Temperature Index. Since virgin stands have recovered from past outbreaks, widespread defoliation need not be viewed with alarm.

Sequential Sampling of Hemlock Sawfly Eggs in Southeast Alaska, by J.S. Hard (88)

In another report on the hemlock sawfly, entomologist Hard describes a sequential sampling technique for estimating egg populations. In this technique, branch samples are examined only until a single egg is found, which greatly reduces the amount of field time. A tree is called ''infested'' if the sample yields one or more eggs, and ''uninfested'' if the sample yields none. Percent of ''infested'' trees determines egg population concentration. The upper limit for an endemic to light population is 33.3 percent ''infested'' sample trees. The lower limit for a moderate to heavy population is 50.0 percent ''infested'' sample trees.

Mortality of Overwintering Eggs of the Black-Headed Budworm and Hemlock Sawfly in Southeast Alaska, by D.C. Schmiege (89)

The black-headed budworm and the hemlock sawfly both overwinter as eggs. Budworm eggs are laid singly on the flat surface of needles of western hemlock and Sitka spruce. Sawfly eggs are deposited singly in notches cut into the edge of western hemlock needles. Fall egg surveys are used to predict budworm and sawfly populations for the following season. Egg mortality between deposition and hatching must be known in order to make accurate population predictions. A study of winter egg mortality was begun in 1962 and completed in 1965. Field work was done at Limestone Inlet near Juneau, Alaska.

Parasites of the Black-Headed Budworm *Acleris gloverana* (Lepidoptera: Tortricidae) in Southeast Alaska, by Torolf R. Torgersen (90)

Studies of budworm parasites in Alaska have been underway since 1953. The purpose of these studies has been to identify the parasites attacking the budworm and to assess their role in regulating host populations.

A key for the identification of parasite adults and notes on the bionomics of each species are given. The list of parasites includes 16 species, contrasting sharply with the 48 species reported from coastal British Columbia. Only two species, *Triclistus pallipes* Holmg, and *Meteorus argyrotaeniae* Johansen, appear in the Alaskan complex that do not also appear in the list from British Columbia.

Oviposition Preference of the Black-Headed Budworm and Host Phenology, by D.C. Schmiege and J.S. Hard (91)

Black-headed budworms prefer hemlock foliage for laying their eggs. This probably accounts for the fact that more severe defoliation has occurred on hemlock than adjacent spruce. During prolonged outbreaks, when hemlock is severely defoliated, budworms may be forced to lay eggs on spruce. It is likely that fewer of these budworm larvae survive because the rapidly expanding spruce shoots do not provide the shelter found in hemlock buds.

Don Schmiege

The Relation of Weather to Two Population Declines of the Black-Headed Budworm in Coastal Alaska, by Donald C. Schmiege (92)

Hot, dry weather accompanied the decline of black-headed budworm populations in coastal Alaska in 1955 and 1965. A study of weather records for the period 1945 to 1965 shows that population collapse occurred in years of unusually warm, dry weather during July. No consistent weather pattern was apparent during the years of population increases. The great reduction in budworm numbers occurred during the larval periods in both 1955 and 1965. No evidence of disease was found in either outbreak.

New Insect Identified

They've probably been in Alaska for cenuries, but entomologists have only recently ound them—a new species of *Spinolochus,* or small wasps (nonstinging) that inhabit orests and parasitize other insects. The newly-discovered species was named *Spinoochus distolatus* Torgersen, by the author who first found this parasitic insect.

See *A New Species of* Spinolochus *from North America,* by Torolf R. Torgersen (93).

The Amount of Foliage Consumed or Destroyed by Laboratory-Reared Larvae of the Black-Headed Budworm, *Acleris variana,* by Richard A. Werner (94)

This study provides data on the number of buds and needles consumed or destroyed by budworm larvae feeding on hemlock and spruce in the laboratory. Since Sitka spruce produces twice as many needles per linear inch of twig as western hemlock, defoliation by the budworm is more severe on hemlock than spruce because of differences in the development of the hosts and in the feeding behavior of first- and second-instar (instar: period of growth between molts) larvae on each of the hosts.

The results of this study can be used to predict the relative amounts of western hemlock and Sitka spruce defoliation expected in areas of known egg populations. Correlations can thus be made by the survey entomologist between expected population levels and expected defoliation.

Development of the Black-Headed Budworm in the Laboratory, by Richard A. Werner (95)

The black-headed budworm, *Acleris variana* (Fernald), is a major defoliating insect in southeast Alaska. The preferred host in Alaska is western hemlock, but defoliation occurs also on Sitka spruce.

In this study, two successive generations of *A. variana* were successfully reared in the laboratory on both western hemlock and Sitka spruce foliage.

There was no difference in development time (egg to adult) between first generation budworms reared at an average temperature of 66° F. (range 58-71°) and second generation budworms reared at 71° F. (range 69-72°). The average development time of budworms (egg to adult) was approximately equal when reared on hemlock and spruce.

Female budworms had a longer life span (88 days) than males (77 days) when reared on either hemlock or spruce. This difference in life span was greatest in the adult stage.

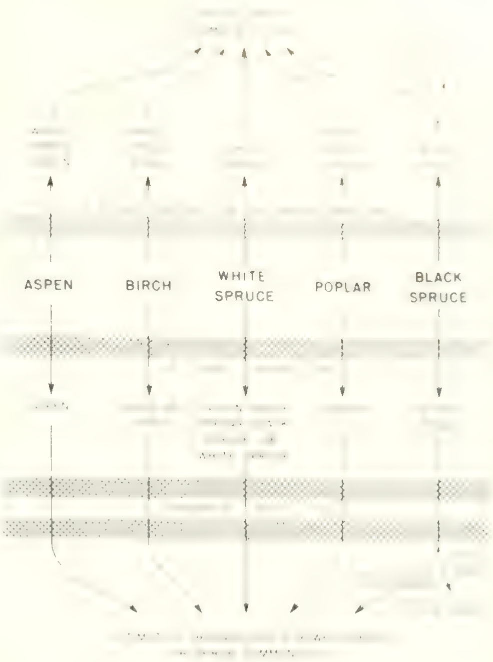
fire and flood

ecology

Ecological Effects of Forest Fires in the Interior of Alaska, by H.J. Lutz (96)

A 121-page bulletin published in 1956 describes the history of forest fires in interior Alaska and the effect of fire on various parts of the ecosystem—forests, soils, watershed characteristics, economic development, and wildlife (fur-bearing animals, moose, and caribou). Information for the study was collected from 103 sample plots.

The forests of interior Alaska are very susceptible to destruction by fire. Low rainfall, long hours of sunshine during the summer, highly flammable ground cover, and coniferous forests, combine to make a high fire hazard.



Changes in forest types following fire.

Most of the fires in the past were caused by man, who, in many parts of the north, tended to live a seminomadic life. Modern man appears to be even less careful with fire. The forests are also subject to fires caused by lightning. Once started, fires may burn for weeks or months, spreading over hundreds of thousands or even millions of acres.

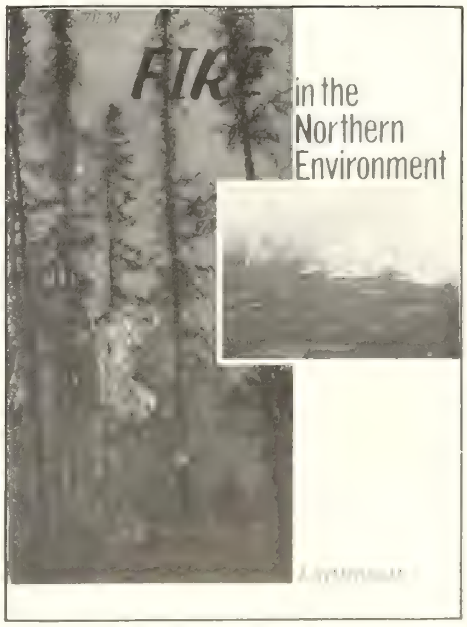
Wildfire in the Taiga of Alaska, by Leslie A. Viereck (97)

The taiga of Alaska consists of a vegetation mosaic resulting primarily from past wildfires. Today (1973), both lightning- and man-caused wildfires burn an average of 400,000 hectares annually, creating vast areas of successional ecosystems. However, although the number of reported fires is increasing, fire control is becoming more effective in limiting the average size of fires and the total area burned.

One of the important influences of fire in the taiga ecosystem is its effect on permafrost and the soil nutrient cycle. Construction of firelines in permafrost areas has a greater effect on soil erosion and situation than does the fire itself.

Some wildlife species, such as moose and snowshoe hare, depend upon fire and its resultant successional plant communities, whereas fire may have deleterious effects on caribou winter range.

Fire has both positive and negative effects on esthetic and recreational values. Fire has always been a part of the Alaska taiga ecosystem; if it is totally excluded from the environment, some major ecological changes will result. Fire-suppression alternatives are discussed and additional research on fire effects suggested.



FIRE in the Northern Environment, Proceedings of a Symposium, edited by C.W. Slaughter, Richard J. Barney, and G.M. Hansen (98)

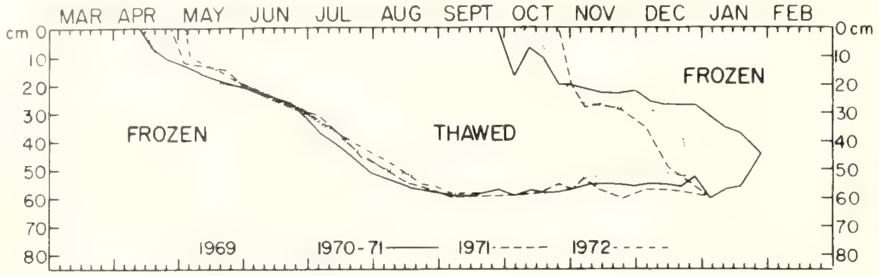
A 275-page summary of all that is known about fire in the northern environment, from a symposium at the University of Alaska in 1971, sponsored by the Alaska Forest Fire Council and the Society of American Foresters. The purpose of the symposium was to explore various aspects of wildfire in the subarctic—its relationship to the natural environment and to man's use of the environment—and fire control.

Ecological Effects of River Flooding and Forest Fires on Permafrost in the Taiga of Alaska, by Leslie A. Viereck (99)

In the taiga of Alaska, permafrost and vegetation are closely related. In areas underlain by permafrost, the nature of the vegetation is important in determining the thickness of the active (melt) layer. In a black spruce/*Ledum*/moss stand, the active layer is normally 30-60 cm thick.

Both flooding and fire can have a profound effect on the permafrost layer. For example, flooding can thaw the permafrost and cause higher soil temperatures in the upper levels. Siltation also results in the compaction and death of the moss layers, and thus increases the active (melt) layer.

Fire has a similar effect on thickening the active layer of permafrost. Although thawing in burned forests the year of the fire may not be significant, by the end of the second summer it may be as much as 160 percent of that in unburned stands. Return to preburn thaw levels takes about 50 years.

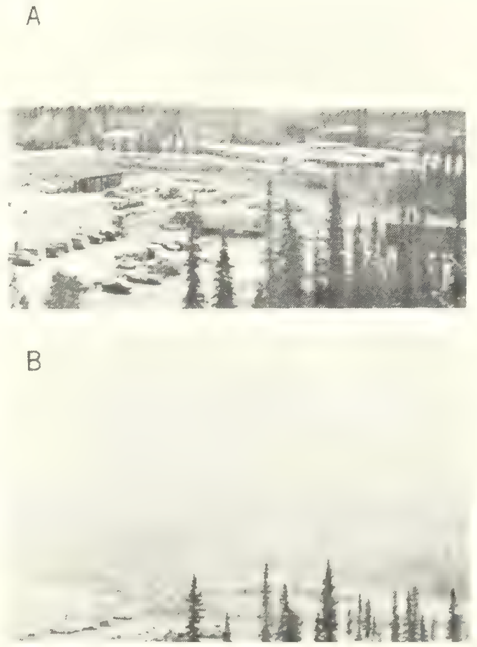


*Four-year record of freeze-thaw cycle in 55-year-old open black spruce/*Ledum*/moss type near Fairbanks.*

Wildfire Smoke Conditions: Interior Alaska, by Richard J. Barney and Erwin R. Berglund (100)

Wildfires are commonplace in Alaska. Aboriginal man, in addition to being careless with fire, started fires to control insects, herd animals, facilitate travel, and dry firewood (Lutz 1956, 1959). Hundreds of wildfires occur each summer—some in excess of 100,000 acres each. In 1969, over 4,000,000 acres were burned. Some of the fires burn for long periods of time, often well into the winter months. Such fire activity under specific meterological conditions results in a smoke pall covering hundreds of square miles and over 5.6 miles thick. From mid-June through mid-July, 1969, an estimated 145,000 cubic miles of smoke persisted in interior Alaska.

In this study, records of 21 stations were analyzed for smoke persistence and visibility. Conditions were better than researchers had previously expected.



A southerly view from the University of Alaska, Fairbanks, overlooking the Tanana River Valley. (A) Clear day; (B) 1969 smoke conditions.

fire danger rating

Fire Danger and Time-of-Day

Daily cyclic patterns in air temperature, relative humidity, and windspeed cause variations in fire behavior. A relationship between time-of-day and spread index was developed for four interior Alaska stations to predict diurnal fluctuation in fire danger for planning fire control operations.

See *A Relationship Between National Fire Danger Rating System Spread Index and Time-of-Day in Interior Alaska,* by Nonan V. Noste (101).

National Fire-Danger Rating System Fine-Fuel Moisture Content Tables—An Alaskan Adaptation, by Richard J. Barney (102)

Fine-fuel moisture content tables have been developed for use with the National Fire-Danger Rating System in Alaska. Comparisons have been made which illustrate differences resulting from danger-rating calculations based on these new fine-fuel moisture tables versus the standard NFDRS tables. New fine-fuel moisture content tables for the cured, transition, and green herbaceous stages of fuel are provided.

Black Spruce Fuel Weights and Biomass in Two Interior Alaska Stands, by Richard J. Barney and Keith Van Cleve (103)

This study reports the fuel weight and biomass distribution in a 51-year-old lowland and a 55-year-old upland black spruce stand in interior Alaska. Biomass distribution is shown for overstory, standing and down dead tree components, herbaceous understory, and the moss layer.

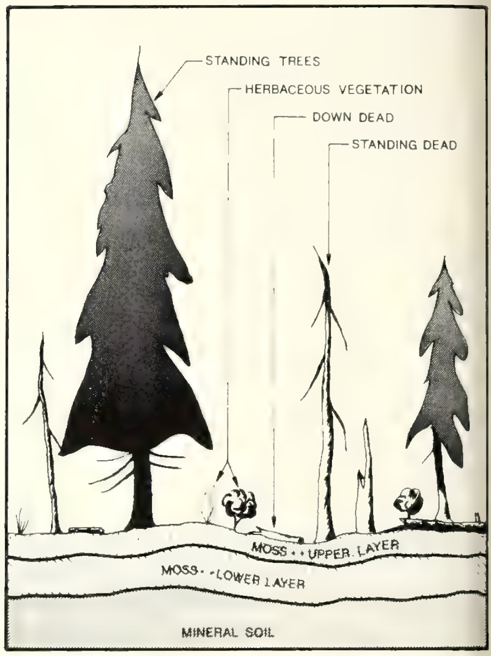
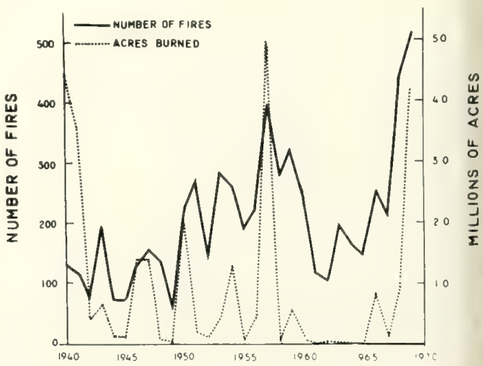


Diagram of stand showing sampling categories.

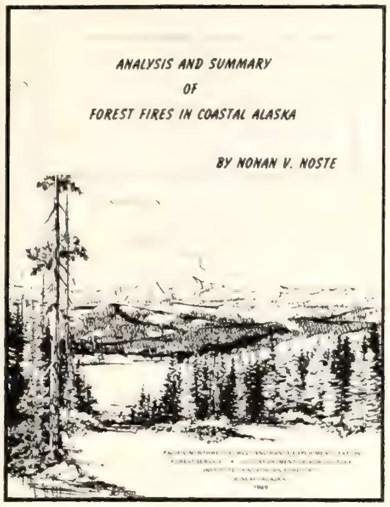
wildfire statistics

Wildfires in Alaska—Some Historical and Projected Effects and Aspects, by Richard J. Barney (104)

This paper discusses some of the historical aspects of wildfires in interior Alaska with particular reference to the period from 1940 to the present. Several speculations are made on the basis of recent records relative to fire impact or effects. The need to obtain quantitative impact information is also discussed.



Number of fires and acres burned by year, interior Alaska, 1940-69.

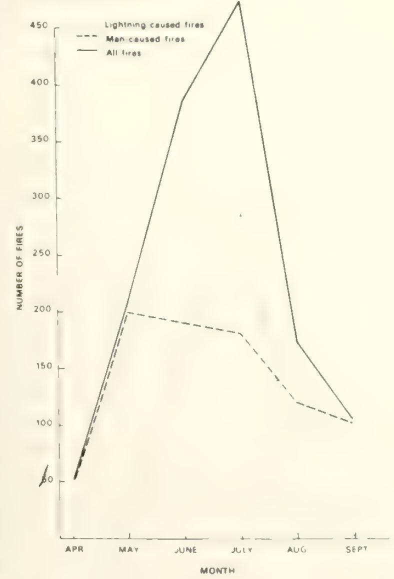


nalysis and Summary of Forest Fires in Coastal Alaska, by Nonan V. Noste (105)

his summary describes the fire problem in astal Alaska and should be useful in de- elopment of both suppression and preven- on plans. The future development of a ronger planning base will require a con- erted effort at recordkeeping to develop od basic fire data. The author and col- agues identify factors associated with fire currence and acreage burned and provide statistical summary. The information is tended to answer questions concerning ho, when, where, and magnitude of the e problem.

elected 1966-69 Interior Alaska Wildfire Statistics With Long-Term Comparisons, by Richard J. Barney (106)

asic historical information is presented on ildfires in the interior of Alaska. The aper presents selected interior Alaska forest nd range wildfire statistics for the period 966-69. Comparisons are made with the ecade 1956-65 and the 30-year period 940-69, which are essentially the total ecorded statistical history on wildfires avail- ble for Alaska.



otal number of fires by cause and month, interior laska, 1966 69.

Wildfires and Thunderstorms on Alaska's North Slopes, by Richard J. Barney and Albert L. Comiskey (107)

Although the North Slope is apparently not a fire-dominated ecosystem, wildfire is not unknown to this arctic environment. The authors have gathered information that shows that five wildfires burned more than 1,600 hectares of tundra on Alaska's Arctic Slope. It was found that environmental conditions suitable for lightning, ignition, and burning occur more often than previously recognized at this northern latitude.

The authors conclude that burnable fuel conditions and thunderstorms will occasionally coincide, thereby creating widely spaced potential wildfire conditions over the Arctic Slope. Man and his activities are another potential ignition source. As his access into the area improves, the probability that he will start fires increases.

A Critical Look at Fire Damage Appraisal, by Nonan V. Noste and James B. Davis (108)

Fire-damage appraisal in relation to fire-protection planning shows a need for a standard appraisal system on all federal lands. Fire control costs and damages on an interior Alaska and a northern Minnesota fire are compared: Application of both Bureau of Land Management and Forest Service appraisal criteria to the Minnesota fire produces considerable differences. Control levels cannot be optimized without relating costs to damage.

1971

FIRE
SEASON
CLIMATIC
ZONES OF MAINLAND ALASKA

william m. trigg

Fire Season Climatic Zones of Mainland Alaska, by William M. Trigg (109)

This paper describes the maximum and minimum fire danger areas on a seasonal basis in Alaska. It further points out where inadequate data exist as well as the location of extreme or peculiar climatic variations. The author suggests that further work of a more detailed nature is probably desirable, but this depends on the needs and capabilities of both fire weather and fire control personnel.

Helicopters and Helibuckets Used to Control Interior Alaska Wildfires, by Roy M. Percival and Nonan V. Noste (110)

Tactical and logistical problems of controlling remote forest firest in Alaska are tied to the vastness of the country and the limited access to the fires. Aircraft in general and fixed-wing retardant planes specifically have traditionally played an important role in supporting operations. Helicopters and helibuckets are proving to be tools well-adapted to dropping water.

Franklin Log Skidder Adapted for Fire-line Use in Alaska, by Robert W. Weber and Richard J. Barney (111)

In order to reduce the impact of fire control activities, the Bureau of Land Management's fire control staff has developed an alternative to cat-built fire lines in Alaska. A Franklin articulated all-terrain log skidder has been adapted for fire-line construction. The skidder has been used not only for direct control activities but also logistical support. The outstanding point of this machine is that there has been no down time in all its use. It can go places that the crawler-type tractor cannot. It does not disturb the surface vegetation to the extent of crawler tractors. In addition to relatively light ground pressure, the machine's ability to turn like a car results in less disturbance to the ground cover than the pivoting action used to turn cats.

Fire control personnel in Alaska feel that this type of machine is well worth considering in other areas of the country as an additional tool in the arsenal of fire control.

Airliner Turns Bomber, by Roy M. Percival and Richard J. Barney (112)

The Bureau of Land Management used a converted DC-6B airliner as a retardant aircraft during the 1971 and 1972 fire seasons. This ship is a significant step toward solving the cost, distance, delivery time, and payload problems encountered in Alaska. Fire control personnel in Alaska generally agree that the DC-6B is a definite advancement in terms of total retardant capabilities and a welcome addition to the aircraft fleet.

Alaska's Extra Ace: Water Dropping, by Nonan V. Noste and Roy M. Percival (113)

A summary of water dropping on interior Alaska wildfire is presented for the 1969 fire season. The study suggests that water dropped from helibuckets can provide a short-term fire control line under certain weather and fuel conditions.

wildlife habitat

interior alaska

land at river's end

the copper river delta

Land at River's End, The Copper River Delta, by Thomas Michael Baugh (114)

The natural resources of the Copper River Delta of the Chugach National Forest, southeast of Cordova, Alaska, have been studied and utilized by man since the turn of the century.

This beautiful 10-page pamphlet, liberally illustrated with color and black and white photographs of the wetlands and its wildlife, traces the history of the area and brings the reader up to date on research and development work taking place on the delta.

The first oil well in Alaska was developed in this area in 1901 and continued producing until 1933. Today, six major oil companies are exploring here for more oil.

In 1962, the Forest Service and the Alaska Department of Fish and Game jointly established a 332,000-acre game management area on the delta which provides vital habitat to tens of thousands of waterfowl in the Pacific Flyway.

The devastating 1964 earthquake distrupted the delicate ecology of the area. The quake disturbed nesting habitat for breeding ducks and their populations fell from 70,000 to between 5,000 to 10,000 birds.

Recent efforts to improve the wildlife habitat of the delta have resulted in benefits to waterfowl. About 10,000 pairs of ducks are again visiting the delta; the dusky Canada goose population, which declined following the 1964 quake, appears to have stabilized; trumpeter swan numbers remain stable with 80 pairs nesting and breeding on the delta each year. Work continues on efforts to establish food for waterfowl in ponds on the delta and to identify present and potential duck and goose habitats.

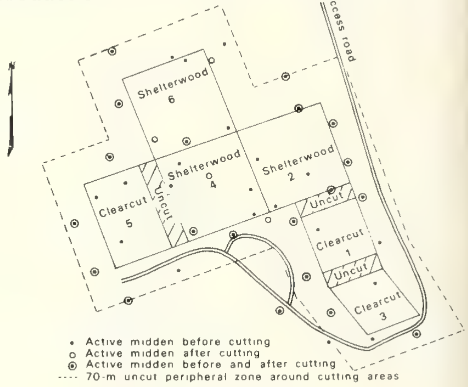
Food Habits of Moose, *Alces alces,* in Alaska: A Preliminary Study Using Rumen Contents Analysis, by Charles T. Cushwa and John Coady (115)

Rumen contents of 166 moose taken in 1971 and 1972 in the Fairbanks and Kenai regions of Alaska were analyzed to determine seasonal food preferences and to understand moose-habitat interactions. The authors compare their findings with data from six studies of other scientists on moose food habits reported for Alaska. Results indicate that there are seasonal and regional variations in habitat utilization by moose.

Browse vegetation favored, when available, was found to primarily twigs of willow, birch, cottonwood, aspen, and alder in winter; willow and birch in spring; willow in summer; and willow and birch in the fall of the year. Depending upon regional availability in these seasons, other items of vegetation less frequently consumed were: fruit, mountain-cranberry, grass, equisetum, lichens, and sedges. Spruce was seldom eaten.

Red Squirrel Response to Clearcut and Shelterwood Systems in Interior Alaska, by Jerry O. Wolff and John C. Zasada (116)

Population response of red squirrels to clearcut and shelterwood silvicultural systems in interior Alaska was determined by comparison of population differences before and after cutting. The conditions imposed by the cutting resulted in the squirrels' vacating clearcuts and in reduction of their numbers in shelterwoods. Populations in adjacent uncut stands remained stable or increased slightly. The long-term suitability of the shelterwood will eventually be determined both by the response of squirrels to the more open stand conditions, especially the spacing of cone-bearing trees, and by cone production.


Access road
Shelterwood 6
Shelterwood 4
Shelterwood 2
Clearcut 5
Uncut
Uncut
Clearcut 1
Uncut
Clearcut 3
• Active midden before cutting
○ Active midden after cutting
⊙ Active midden before and after cutting
---- 70-m uncut peripheral zone around cutting areas

Map of cutting units.

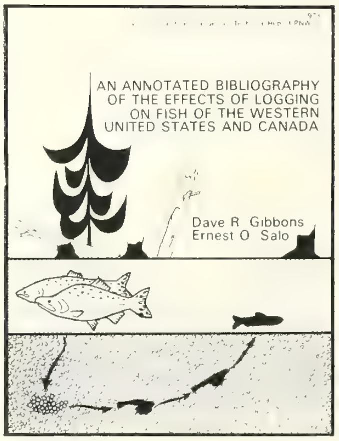
southeast alaska

Effects of Log Dumping and Rafting on the Marine Environment of Southeast Alaska, by Bruce C. Pease (117)

Because of the water-oriented geography and lack of roads on the islands of southeast Alaska, most commercially harvested timber is stored and transported on marine waters.

This report summarizes the extent of water-dependent log handling and storage facilities in southeast Alaska and reviews available literature on the environmental impact of these facilities. Field studies were conducted at 16 sites and correlated with laboratory studies of leaching rates and toxicity of the four major wood species harvested in southeast Alaska. Significant effects on water quality are believed to occur only under unique conditions and were observed at only 2 of the 16 study sites.

Active log dump at Thorne Bay.



AN ANNOTATED BIBLIOGRAPHY OF THE EFFECTS OF LOGGING ON FISH OF THE WESTERN UNITED STATES AND CANADA

Dave R. Gibbons
Ernest O. Salo

An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada, by Dave R. Gibbons and Ernest O. Salo (118)

This bibliography is an annotation of scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the Western United States and Canada. It includes 278 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids, multiple logging effects, alteration of streamflow, stream protection, multiple-use management, streamside vegetation, stream improvement, and descriptions of studies on effects of logging. A review of the literature, a narrative on the state of the art, and a list of research needs determined by questionnaires are included.

Bill Meehan

Toxicity of Various Formulations of 2,4-D to Salmonids in Southeast Alaska, by William R. Meehan, Logan A. Norris, and Howard S. Sears (119)

Because the U.S. Forest Service is using 2,4-D for vegetation control in southeast Alaska, this study was undertaken to test the chemical's toxicity to salmonid fishes using forest streams in that region. Different concentrations were tested for their effects upon pink, chum, coho, and sockeye salmon, Dolly Varden char, and rainbow trout in southeast Alaska. A comparable test was made in Oregon using coho salmon fingerlings.

At less than 50 ppm, 2,4-D acid produced no mortality except in pink salmon fry. The butyl ester was most toxic causing nearly complete mortality in all species at concentrations > 1.0 ppm and the isooctyl ester was found to be the least toxic of the ester formulations. Alaskan and Oregon coho fingerlings were similar in their responses to 2,4-D acid, butyl, and isooctyl esters. The toxicities of three different formulations of isooctyl ester, a PGBE ester, and butyl ester to Alaskan coho fingerlings were also determined. There were few or no differences in toxicity among isooctyl ester formulations. The butyl and PGBE esters were similar in toxicity.

Residues in Fish, Wildlife, and Estuaries, by Howard S. Sears and William R. Meehan (120)

About 400 acres of cutover land on the Nakwasina River watershed in southeastern Alaska were sprayed with 2,4-D to inhibit growth of broad-leaved plants. It was found that samples of water and fish had concentrations of 2,4-D well below the level considered lethal to aquatic organisms. No immediate mortality to salmonid fishes or aquatic invertebrates was attributable to the spray.

The results were considered inconclusive because of the lack of information on the pretreatment condition of the test animals. Further research is required to assess the immediate and long-term effects of these spray operations in Alaska.

Effects of Forest Fertilization on Two Southeast Alaska Streams, by William R. Meehan, Frederick B. Lotspeich, and Ernst W. Mueller (121)

Basic productivity and water quality were studied to determine the effects of forest fertilization with urea.

An initial, short-term increase in ammonia-nitrogen was observed in the treated streams, and nitrate-nitrogen levels increased and remained high compared to control stream levels during the year following treatment. Concentrations did not approach those considered toxic to aquatic life or unsafe for human consumption. Changes in biomass of periphyton and benthic fauna as a result of fertilization were not detected.

Some Effects of Shade Cover on Stream Temperature in Southeast Alaska, by William R. Meehan (122)

Probably the most important effect of streamside vegetation on water temperature is the biological significance of increased temperatures.

Water temperatures were recorded in several southeast Alaska streams with a portable thermometer accurate to 0.01° C. Measurements were made at 20-yard intervals in shaded and unshaded reaches and on cloudy and clear days. Results indicate that the effects of streamside cover on stream temperatures can be evaluated by this technique, and that shade-producing streamside cover is important in maintaining cool water, especially during warm, clear weather. The results further indicate that temperature increases after clearcutting in this region do not usually approach lethal limits for fish populations.

Effects of Gravel Cleaning on Bottom Organisms in Three Southeast Alaska Streams, by William R. Meehan (123)

In efforts to improve salmon spawning habitat in streams of Alaska's national forests, the Forest Service has been instrumental in development and use of a machine for "cleaning" streambed gravels. The "riffle sifter," as it is called, is a self-powered amphibious vehicle that stirs up the streambed gravel and then sucks up the fine materials and sprays them out onto the streambanks. This report presents an evaluation of some of the effects of the riffle sifter on populations of bottom fauna in some typical salmon streams in southeastern Alaska.

Measurements of the numbers of insects, annelids (worms), and amphipods (crustaceans) were made before cleaning the gravels, then immediately after cleaning, 3 months later, and finally 12 months later. The cleaning initially reduced the bottom fauna populations in each of the streams, but within 1 year these populations apparently returned to the pretreatment levels.

The riffle sifter in operation.

stream sampling

Comparative Effectiveness of the Standard Surber Sampler and a Hydraulic Modification for Estimating Bottom Fauna Populations, by William R. Meehan and Steven T. Elliott (124)

For more than 30 years, aquatic biologists have been using the Surber square-foot bottom sampler to obtain measurements of stream bottom fauna. This sampler consists of two brass frames, each 1 foot square, hinged together so that they form a right angle when extended. One frame then fits over the square foot of streambed to be sampled, and the other is provided with a net into which organisms drift as they are dislodged from the streambed. In practice, the biologist hand stirs the bottom material within the square-foot area to a depth of a few inches. The dislodged organisms then drift into the collecting net.

The Surber sampler was modified for use with a hydraulic unit to dislodge the bottom organisms in the stream. Comparative tests were conducted to determine the relative effectiveness of each.

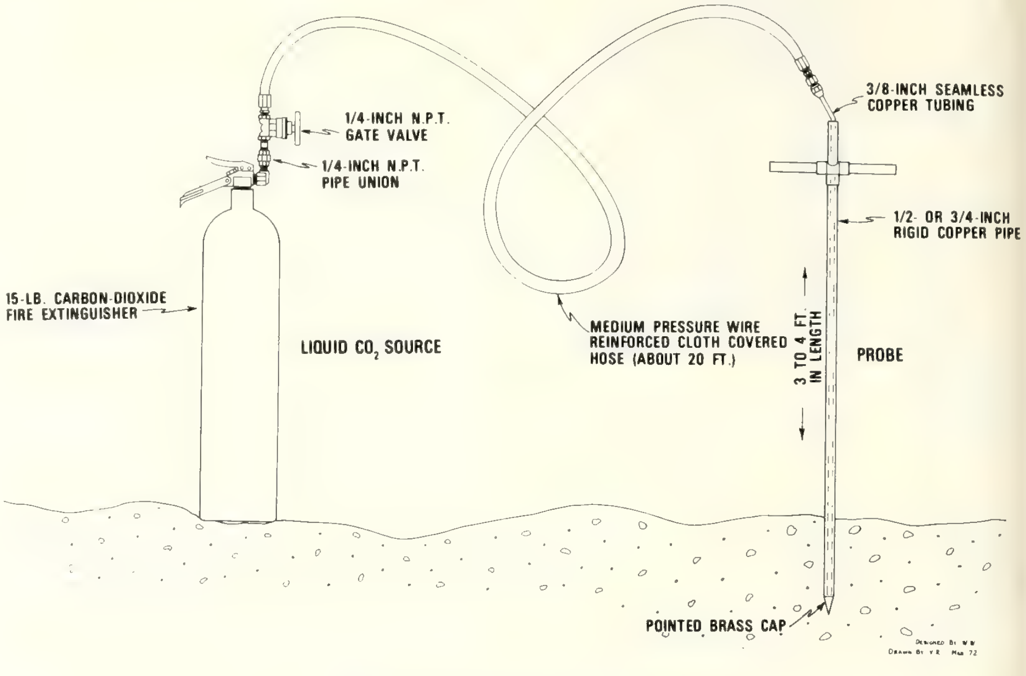
Both techniques are best suited for sampling streambeds composed of fine to coarse gravels and small stones, with water velocities sufficient to pass organisms downstream into the collecting net. Each of the two methods has advantages and disadvantages. The Surber technique is more portable for sampling in areas not readily accessible. It is a better method in areas where water currents are slow, and where streambeds contain considerable silt, sand, or fine organic materials. The hydraulic unit does a more thorough job of stirring up the substrate and is faster and handier for obtaining many samples from a small area. It is more effective for sampling organisms in deeper lying sediments.

A Freezing Technique for Sampling Streambed Gravel, by William J. Walkotten (125)

The need to sample gravel and sediment in rocky, salmon-producing streams of southeast Alaska has led to the development of a freezing technique based on the author's method of using liquid carbon dioxide fed into a copper tube inserted into the gravel.

The liquid CO_2 vaporizes at atmospheric pressure and absorbs heat from the streambed, freezing the intergravel water. Once frozen, the sample is not easily damaged by removal from the sampling site. The technique provides a sample varying in size with the type of streambed material at the sampling location.

The method provides a nearly undisturbed, stratified sample containing stream gravel, intergravel water, and organic material. It should provide valuable information on gravel resedimentation after cleaning and can be used to remove samples from less compact soil types.


1/4-INCH N.P.T. GATE VALVE
1/4-INCH N.P.T. PIPE UNION
3/8-INCH SEAMLESS COPPER TUBING
1/2- OR 3/4-INCH RIGID COPPER PIPE
15-LB. CARBON-DIOXIDE FIRE EXTINGUISHER
LIQUID CO_2 SOURCE
MEDIUM PRESSURE WIRE REINFORCED CLOTH COVERED HOSE (ABOUT 20 FT.)
3 TO 4 FT. IN LENGTH
PROBE
POINTED BRASS CAP
DESIGNED BY W.W.
DRAWN BY V.R. MAR 72

Equipment for freeze-sampling streambed gravel.

alaska - bibliography

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gadgets

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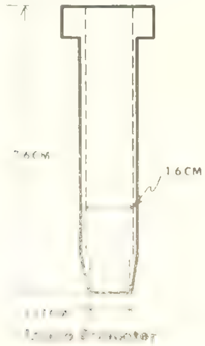
Nothing grabs people quite as much as gadgets. Many PNW researchers are working near the outer limits of scientific knowledge. They are delving into areas of the natural sciences so basic that often they must design and build their own scientific instrumentation and develop new research methods.

This instrumentation ranges from tools as simple as a specialized ratchet wrench to fully automated weather recording stations. Advances in methodology include a variety of sampling techniques, the adaptation of visual equipment for specialized tasks, the use of drugs to immobilize large animals, and many other ways of getting the research job done.

Although instrumentation and methodology are complex subjects, the word often encountered in PNW reports on the subject is "simple." Researchers want to develop easier ways to do their jobs. This benefits both those who use research results and those who adopt the tools and methods for other purposes.

Sampling Yeast and Bacteria

Plant Pathologist Don Knutson has devised a way of sampling yeasts and bacteria in sound wood. Don uses a hollow steel chisel (see diagram) to extract a core sample of wood. This allows him to quantify the relative numbers of microbes in a tree. In his paper (1) Don also describes a system for analyzing the yeast and bacteria content of the wood sample once it is taken.



A Sagebrush Weather Station

W.B. Fowler and J.D. Helvey of the Forest Hydrology Laboratory in Wenatchee, Washington, tell us that big sagebrush *(Artemisia tridentata)* can provide important clues about weather patterns in Washington's Columbia Basin. In a December 1974 article in the magazine *Pacific Search* (2) the authors explain how the width of rings on sagebrush can be used to determine past precipitation.

It's Cold Outside

If rotted wood tends to squish and crumble while making a ring count, use a technique developed by PNW researchers Francis R. Herman and Clark E. Smith. Herman and Smith use a system of freezing wood samples for tree stem analysis. Transverse sections of rotten wood are first submersed in water for several hours and then frozen.

Partially decayed Douglas-fir radial section, frozen to provide accurate ring measurement data.

There's an interesting story behind the "discovery" of this method. A large, 400-year-old Douglas-fir with brown cubical butt rot had been felled for stem analysis. "Using conventional techniques in a rainstorm, we attempted to count the rings and measure sequential radial growth in the rotten heartwood," the authors indicate. "The decayed wood tissue crumbled easily and, even though the thinnest, sharpest razor blade available was used, ring measurements and counts could not be made."

Giving it up for the evening, the two researchers retired to the warmth of their fire. It was cold that night and. . . . "The following morning the rotten stump and breast-high-cut sections were frozen. Sequential radial ring-growth measurements and counts were made with ease" (3).

Photographic Data Recorder For Lumber

W.Y. Pong and G.A. McLaughlin have combined a camera control circuit with a cine pulse Traid Corporation Automax Model G-3 camera and added a built-in strobe light contact and a footage counter to produce a photographic data recorder for use in recording information about individual pieces of lumber as they are produced in a sawmill.

A schematic of the system along with the information necessary to put it together was first reported in the *Forest Products Journal* in 1975 (4).

The researchers report that the system was successfully used over 160,000 times in eight recovery studies. The use of the control unit is obviously not restricted to lumber recovery studies but can be applied to almost any conveyor belt type of operation.

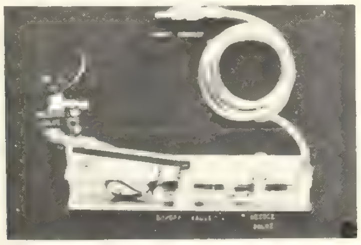
Francis Herman

The Ratchet Racket

Mensurationist Francis R. Herman has developed a ratchet wrench and cleaning equipment for increment borers (5) and followed that up with an improved adaptor for an ncrement borer ratchet assembly (6). If core samples are your thing, you'll be interested n both of these papers.

Measuring Stomatal Aperatures

If a portable apparatus for estimating stomatal aperatures in conifers sounds like something that takes place in your local hospital, then you are in the wrong section of this almanac. Stomata are the small openings in the epidermis of leaves or needles. William Lopushinsky has developed a way to measure these openings. The beauty of this device is its portability. A handful of equipment, a squeeze bottle of alcohol, and a few minutes work result in an accurate measure of stomatal opening in hard-to-measure conifers (7).



Assembled needle chamber, bottom view.

Estimating the Weight of Brush

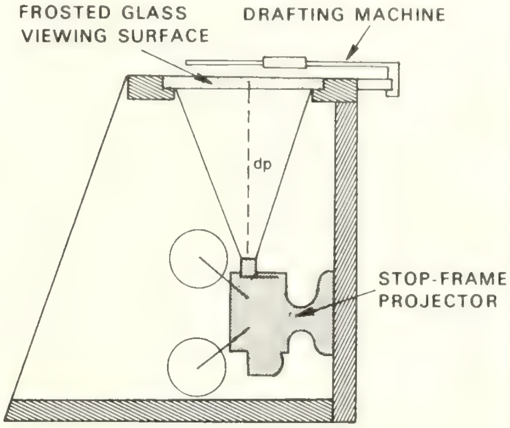
Shrubby vegetation, important as fuel for forest fires and browse for game animals, is extremely difficult to measure. George R. Fahnestock and William K. Key have developed a photo method for estimating the weight and other characteristics of shrubby vegetation for a fraction of the cost involved n actual physical sampling.

The method involves photographing a standard thickness of vegetation, projecting the photographs onto a dot grid, and determining the weight by counting dots and applyng a ratio from actual measurements (8).

Fire Photography

Photography has also been used by Research Forester Stewart G. Pickford to collect data on prescribed burning experiments.

Pickford uses two 16mm moving film cameras, located at separate spots to record fire events. The premeasured, triangulated films are then projected simultaneously on the frosted glass viewing surface with stop frame projectors. Smoke plume velocities and the volume of flow rates of gases have been estimated with this photo technique (9).



A Little More Fire Photography

Gathering information about an in-progress wildfire can be difficult. John D. Dell and Raymond T. Steiger suggest that a portable TV camera-video tape system provides an excellent tool for expanding fire information. This system was used during the project fires which occurred in north-central Washington in 1970.

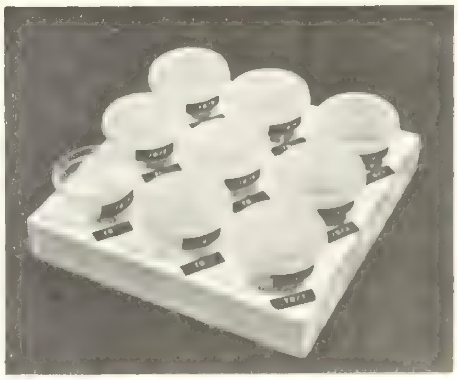
Viedo-tape films of the fires were used to brief overhead teams with data gathered sometimes only minutes before the briefing session was held. The video tapes provided information concerning fuels, topography, and expected fire behavior as well as additional key information (10).

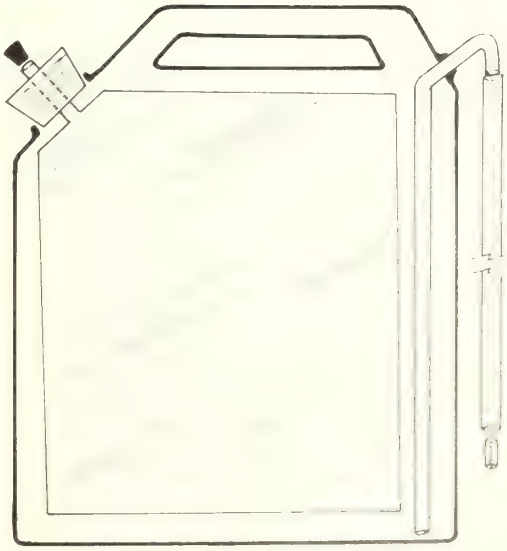
The equipment: (1) portable videocorder and video camera with microphone hookup; (2) 18-inch TV monitor-receiver; (3) playback unit; and (4) ½-inch magnetic video tape.

In The Cups

A quick and economic method has been developed to measure ground distribution patterns of water and fire-retarding liquids dropped from a helicopter in the field.

The equipment is basically simple and includes plastic cups and wooden block cup holders which are placed on a grid marked on the drop site. The entire system is described in *A Field Method For Measuring Patterns of Water Dropped From Helicopters,* by Nonan V. Noste (11).





Waterpowered Air Sampler

Most air quality studies are made in urban areas where electricity can be used to power air samplers. PNW researchers have gone one better and developed a portable water-powered air sampler.

This is a simple, easily constructed device using polyethylene tubing, several rubber stoppers, a 2½-gallon plastic jug containing a Mylar bag and a ¼-inch Tygon head tube (see diagram).

The pumping action is provided by water siphoned from a plastic container at a known flow rate. The water removed is replaced by air drawn into a Mylar sample bag in the plastic jug. The samples are then analyzed in an infrared gas analyzer (12).

Manmade Impacts

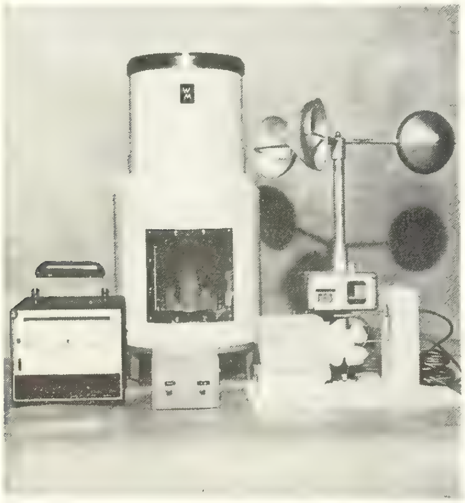
The increase in land use planning activity has led to a growing concern for methods of measuring the impacts of human activity. Michimasa Kojima and J. Alan Wagar have evaluated four methods to measure and evaluate these activities in roadway environments. The two researchers have used ground surveillance, ground photography, and large and small scale aerial photography and have compared the effectiveness of the four techniques (13).

Automated Weather Station

A 31-day battery operated recording weather station has been developed to monitor meteorological information in accessible and remote sites. The station records both wet and dry bulb temperatures, wind speed, and rainfall.

Most of the components are off-the-shelf items. The only fabrications necessary are a battery saver, a psychrometer and a fan assembly. The battery saver is designed to eliminate excessive battery drain when the contracting transducers remain in the "on" or closed position for long periods.

The appeal of this system is its basic simplicity and the fact that some long, hard walks may be avoided due to the 31-day unattended operating period (14).



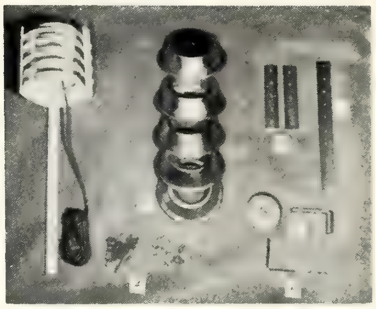
Front row, left to right: recorder, "battery saver," psychrometer. Back row: tipping bucket rain gauge, anemometer.

Wind Analyzer

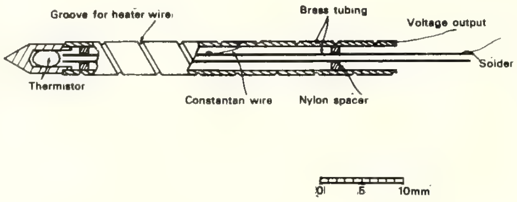
Hardware combined with C-MOS computer technology has led to the development of a versatile wind analyzer for long, unattended runs. The instrument uses the time required for wind to travel 1/12 mile past the station as its basic measurement. Low power requirements enable bimonthly data collection (15).

Keeping The Sun Out

Richard J. Barney has come up with an inexpensive meteorological radiation shield for thermistors and thermocouples which blocks the effects of solar radiation. He put small aluminum pans or anodized aluminum ashtrays in a special stacking arrangement to shield the heat measuring devices. He found that between 0° and 50°F. the aluminum shelters gave 1° higher readings than the standard Cotton Region shelter and 2° higher between 51° and 100°F. (16).



At left, an assembled model with thermistor attached. (1) pie pans, (2) braces, (3) main support, (4) "pop rivets" and washers, (5) bottom radiation shield and mounting bracket, (6) thermistor.



Measuring Snow Density

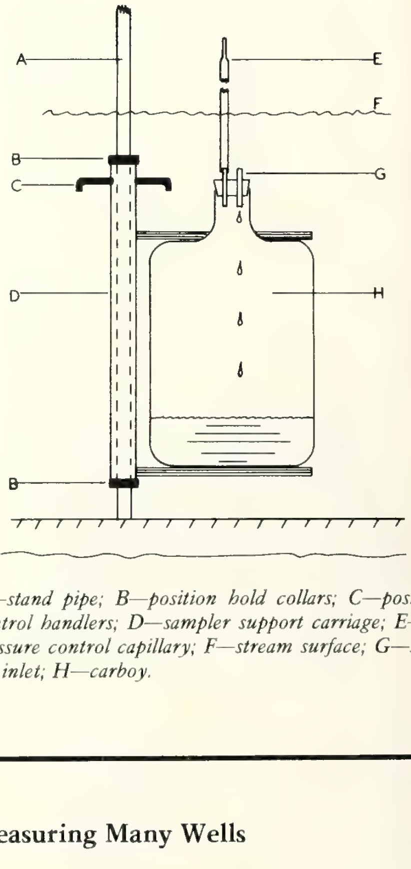
W.B. Fowler at the Forest Hydrology Laboratory in Wenatchee, Washington, has proposed using thermal conductivity to measure snow density. The method uses a special probe and is based on the fact that thermal conductivity is related to the density of the medium being measured, in this case snow (17).

Powerless Stream Sampler

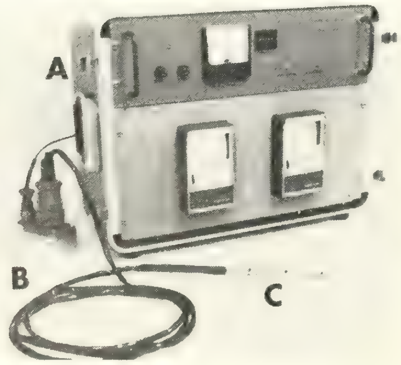
A stream sampler with no exterior energy requirements or moving parts has been designed and tested by PNW scientists. For about $10 you can build the basic unit using simple equipment such as stand pipes, rubber stoppers and a jug known as a carboy. The support equipment adds a little to the cost.

This is one of those items that makes you shake your head wondering why somebody didn't come up with it before. Here's how it works.

The carboy is submerged to the desired depth. Water enters the carboy through a 3-millimeter inside diameter tube. In order for the water to enter, an equal amount of air is released from the exhaust tube. The sampling rate is dictated by a small diameter capillary inserted at the end of the exhaust tube. Increasing the waterhead on the intake tube increases the carboy air pressure, consequently increasing the air outflow and water inflow. Beautiful! (18).



A—stand pipe; B—position hold collars; C—position control handlers; D—sampler support carriage; E—air pressure control capillary; F—stream surface; G—sample inlet; H—carboy.



Recording console shown with one of the multiplexer boxes and one well probe.

Measuring Many Wells

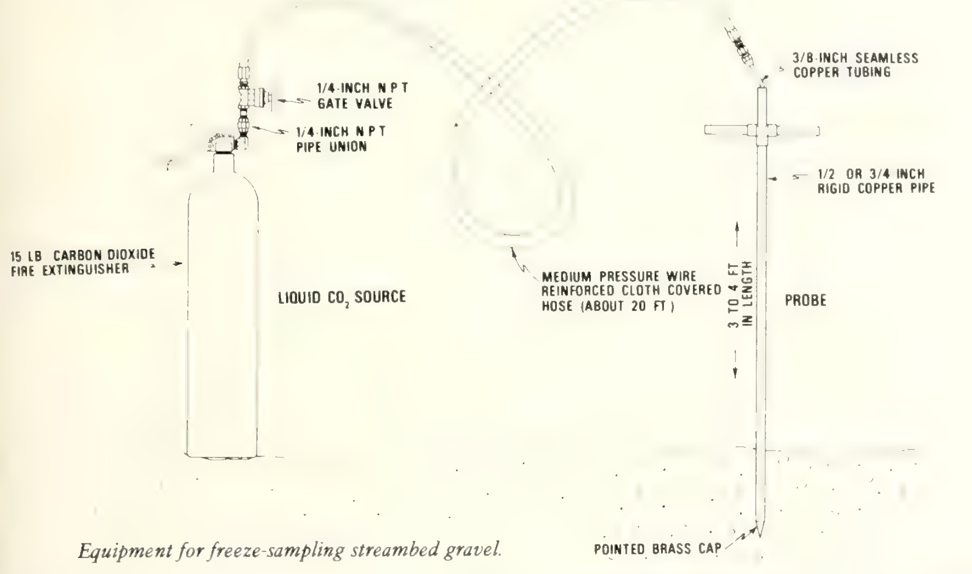
An automated data system has been developed for metering fairly rapid changes in the level of the free water surface in shallow wells. The system is applicable to multiple-well measurements involving the use of 16 well probes and multiplexer boxes coupled to gated-event pen drivers and channel recorders with some rather sophisticated circuitry (19).

Freeze the Creek

The Walkotten gravel freeze sampler enables a biologist to remove a plug of frozen gravel from a streambed. To take a sample, a hollow copper probe is inserted in the streambed. Liquid carbon dioxide is then pumped into the probe. When the probe is pulled out, the frozen core sample comes out with it.

The equipment needed for this device is inexpensive and easy to obtain and assemble. The sampling probe is built from 1/2- or 3/4-inch hard-drawn copper pipe and fittings. To begin, solder a four-way cross pipe to about 3 feet of pipe. Six- to eight-inch lengths of pipe are then soldered to the remaining openings on the four-way cross to finish the handle.

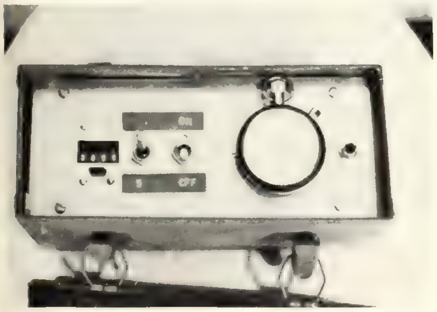
A watertight joint is soldered to the far end of the probe. To complete the assembly, cut a length of 3/8-inch soft-drawn copper tubing long enough to reach the bottom of the probe and connect the tubing to a flared fitting on the upper end of the probe. Add a wire reinforced CO_2 delivery hose, and you're in business (20).


1/4-INCH N P T GATE VALVE
1/4-INCH N P T PIPE UNION
15 LB CARBON DIOXIDE FIRE EXTINGUISHER
LIQUID CO2 SOURCE
MEDIUM PRESSURE WIRE REINFORCED CLOTH COVERED HOSE (ABOUT 20 FT)
3/8-INCH SEAMLESS COPPER TUBING
1/2 OR 3/4 INCH RIGID COPPER PIPE
3 TO 4 FT IN LENGTH
PROBE
POINTED BRASS CAP

Equipment for freeze-sampling streambed gravel.

Cheap at Twice the Price

Meteorologist W.B. Fowler has designed a low-cost (under $35) counter assembly that will replace earphones for current measurements in streams. According to Fowler, the system is more accurate than audio counts and significantly less expensive than some equipment presently available (21).



Exterior view of completed counter assembly.

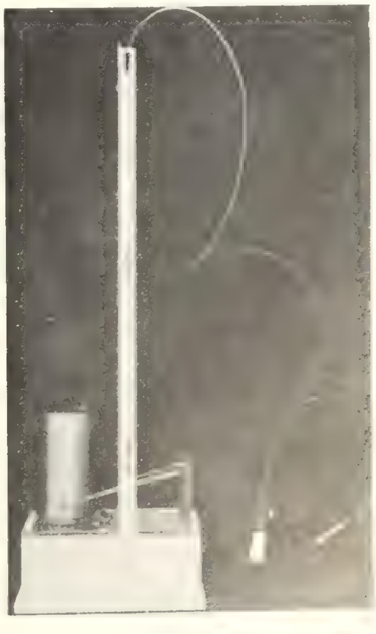
Toothpick Sampling

Searching for inhibitory fungi? If so, check a 1969 paper by PNW microbiologists and mycologists (22). The paper describes a simple, quantitative method of assaying soils for fungi. The system uses birch toothpick probes to transfer the isolates to a double-layered agar plate containing the pathogen mycelium which is sandwiched between the agar layers.

Walkotten Does It Again

William J. Walkotten has done it again with a recording soil moisture tensiometer which provides a continuous record of soil moisture tension for periods of up to 31 days. The instrument detects small moisture changes and diurnal fluctuations.

Walkotten says this instrument can be built for less than $150. If you need one that may be cheap! (23).



Rocks That Glow in the Light

Tracing movement and dispersion of soil-sized fluorescent particles is a promising method for detecting and describing soil erosion. Actively eroding and stable sites are easily identified along with particle size and possible causes. The equipment is simple and consists of natural ore containing fluorescent willemite which responds to ultraviolet light generated by inexpensive mineral-prospecting lamps (24).

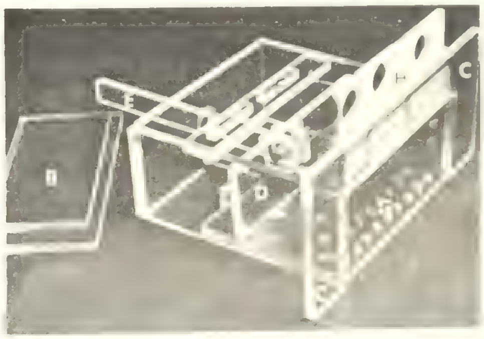
Shooting Elk

Looking for a method to immobilize elk? If so, try dry powder charges of succinylcholine chloride. Wildlife biologists Richard J. Pedersen and Jack Ward Thomas applied this method to 78 Rocky Mountain elk (*Cervus canadensis nelsoni*). The average dosage was 26.4 mg. It took an average of 7.1 minutes before the drug took effect and the drug lasted an average of 24.5 minutes (25).

Photographing Fish

Estimating the dry weight of live, unanesthetized fish can be done photographically. Photographic recording reduces the amount of stress suffered by the fish and makes it unnecessary to use anesthetics.

Fish are slippery creatures and it's generally difficult to get a good side view. To accomplish this task, PNW researcher Clifford L. Hawkes has built an adjustable plexiglass holding device which fits on the inside of an aquarium. Electronic flash at 1/1000 of a second is used to eliminate any movement problems not handled by the holding device.



From this point on, the process becomes a little complicated and it would be best to get a copy of Hawkes' paper which includes a discussion of film and processing techniques and the equations used to establish the weight values.

This technique of photographically measuring fish, constructing regression equations and subsequently measuring live, experimental fish is valuable for stress studies on fish growth where handling must be reduced to a minimum (26).

Double Agent HSUSX

In 1972, Franklin Ward and John D. Dell adapted a hydraulic seeder for use with fire retardants. They tested a Finn Super 1000 Hydroseeder Model HSUSX and found it useful for the general application of retardants as well as for the treatment of areas on steep cutbanks located above roads (27).

A Handy-Dandy Seed Cleaner

Robert F. Woollard and Roy R. Silen have developed an all-pneumatic laboratory seed cleaner using simple equipment such as plexiglass tubing, a vacuum cleaner regulated by a laboratory rheostat and a 1-quart seed container.

This device was developed because of the need for a convenient, compact, gentle seed cleaning apparatus for small seed lots of various species.

The two-staged aspirator used for seed cleaning is constructed from large diameter plexiglass tubing. A blower is mounted on top of the aspirator and a vacuum cleaner is connected at the bottom.

Prior to cleaning, all large debris is removed for the seed sample by screening through a ½-inch wire screen. Seed wings are removed by hand and the seeds are then placed in the aspirator. The entire process for a quart-sized lot of seeds requires from 1-3 minutes (28).

A Seed Extractor

Researchers in Alaska needed a compact seed extractor that could be stowed away when not in use. Finding none on the market, they designed and built one. It has a capacity of one-half bushel of dry cones, is simple, sturdy, and can be built in a few hours.

The extractor consists of a plywood box cut in two and hinged to provide a deep lid and fitted with a revolving drum and a removable drawer. It is powered by a ¼-horsepower electric motor, belted through two pairs of pulleys and an idler shaft to provide a drum speed of 60 r.p.m. At greater speeds, centrifugal force prevents cones from tumbling properly.

A list of materials is included. Cost of the materials was about $75. See *A Compact Laboratory Seed Extractor,* by A.S. Harris (29).

Symbolic Plants

Look no further for an easy, failsafe method of representing plants by symbols. In 1967, the PNW Station printed the third edition of *Northwest Range Plant Symbols* (30). This book-sized publication has been so popular that a fourth edition has been printed.

Northwest Range Plant Symbols uses a fairly easy system for the identification of plants occurring in Washington, Oregon, and Idaho. The first two letters of the Latin genus and species name are combined to form a symbol. Thus, fairway crested wheatgrass, also known as *Agropyron cristatum,* becomes AGCR.

The alpha-numerical code takes no more than six spaces. This simplifies the transfer of data from field sheets to punch cards. The system was originally devised before the widescale use of alpha codes. For this reason each plant is also listed with a numerical code.

The system is widely used throughout the three state area and has been adapted for other areas. As a spin-off, George Garrison, who led the effort to develop the symbol system, says that the publication is one of the best things to happen to the biological secretary. Miss, Ms., or sometimes Mr. Jones can now translate *Epilobium alpimum gracillium* into alpine willow herb.

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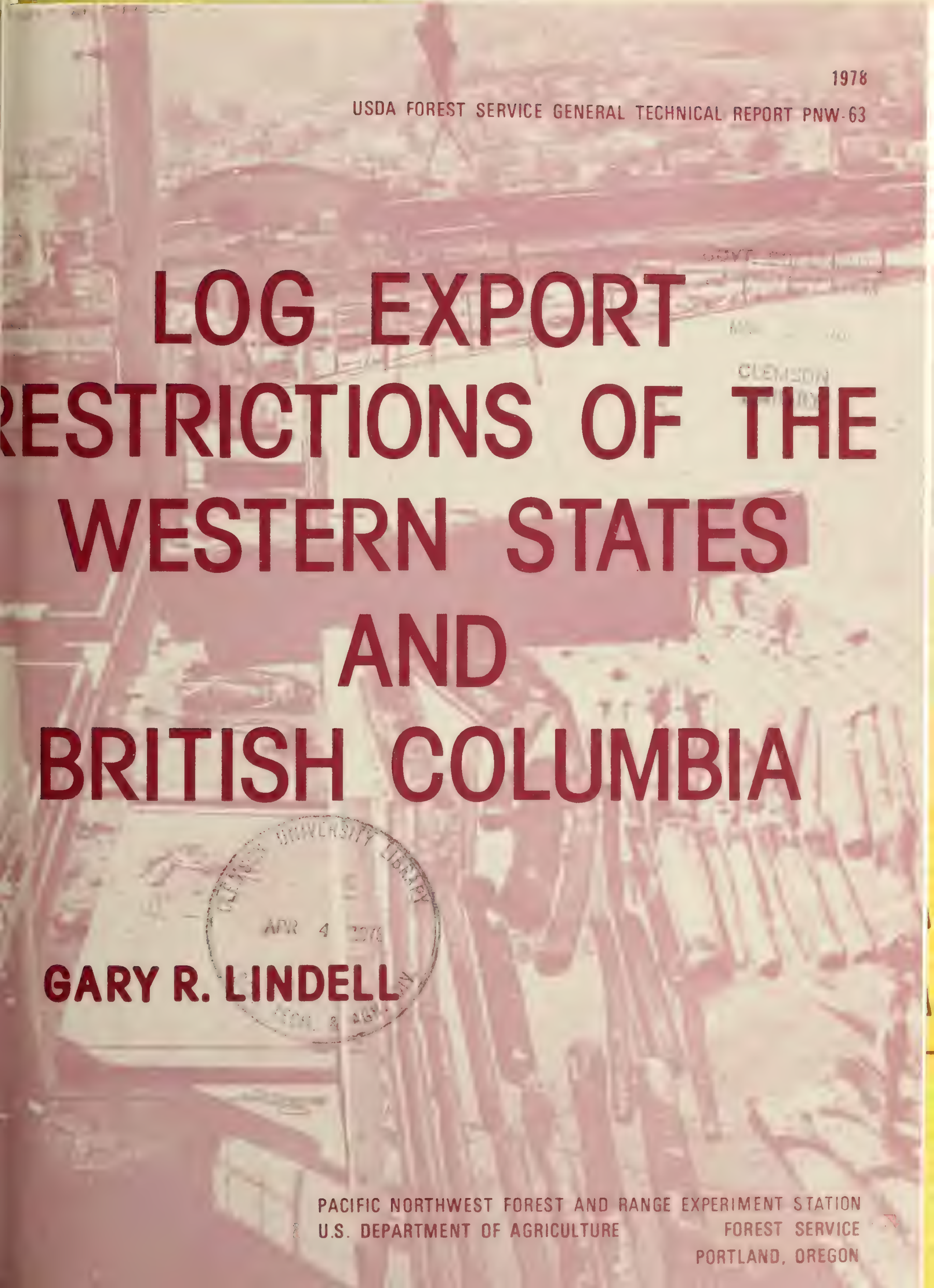

1978

USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-63

LOG EXPORT RESTRICTIONS OF THE WESTERN STATES AND BRITISH COLUMBIA

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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

Highlights

The export of unprocessed timber is restricted from lands managed by the U.S. Forest Service and the Bureau of Land Management in the West. Lumber, chips, veneer and plywood, poles and piling, and cants 8-3/4 inches in thickness or less are defined as processed and thus eligible for export. Port-Orford-cedar and Alaska-cedar have been found surplus to domestic needs and thus eligible for export in unprocessed form from Forest Service and Bureau of Land Management lands in the contiguous United States. Alaska-cedar and western redcedar logs may be exported from certain Forest Service lands in Alaska.

In addition to regulations restricting the export of Federal timber, the Forest Service and Bureau of Land Management have implemented regulations to ensure that Federal timber is not substituted for private timber which is exported. This is accomplished by comparing a purchaser's buying and export activity for a particular year with that of his historical level or pattern. The Forest Service defines a purchaser's historical level as equal to 110 percent of his average annual volume of Federal timber bought or exported during the calendar years 1971, 1972, and 1973. In the case of the Bureau of Land Management, a purchaser's historical pattern is established by his purchases of Federal timber and exports of private timber for the 12-month period preceding the date of his last export sale. Purchase and export activity in excess of the historical level or pattern constitutes substitution.

The export of unprocessed timber is also restricted from lands managed by the States of Alaska, Oregon, California, and Idaho. The definition of unprocessed timber varies from State to State. In addition, California has enacted regulations to prevent the substitution of timber from State-managed lands for private timber which is exported. Approximately one-third of the 1975 timber harvest from Washington, Oregon, and California was directly prohibited from export by either Federal or State controls.

All export of timber from the Province of British Columbia is subject to the approval of the Dominion government; some is also subject to Provincial control. The export of logs or chips is permitted when it has been established that these are surplus to domestic needs. In addition, logs exported from lands under Provincial control are subject to an export tax.

KEYWORDS: Import/export (forest products), trade policy (international), legislation.

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The pros and cons of softwood log exports from the West Coast have been debated for over a decade. Initially, the export market was generally viewed with favor, particularly during the early 1960's as a needed outlet for salvaged timber. But as exports grew with time and accounted for a growing share of the timber harvest, concerns were expressed as to the propriety of allowing the unrestricted export of logs (figs. 1 and 2). In response

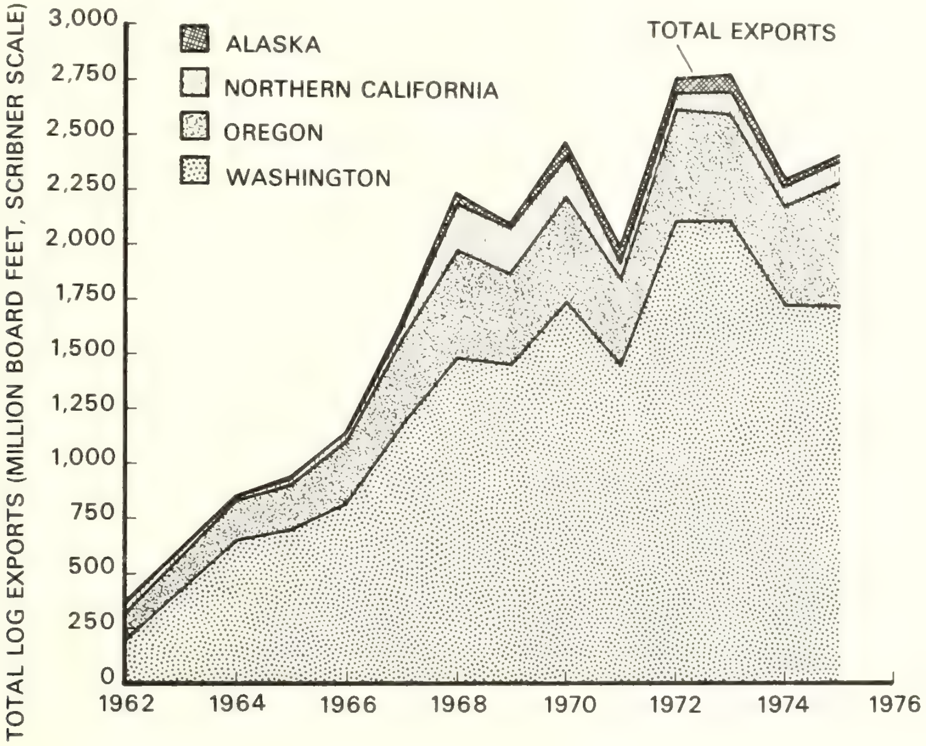

Figure 1.--Softwood log exports from ports in Washington, Oregon, northern California, and Alaska, 1962-75. Source: Ruderman (1976).

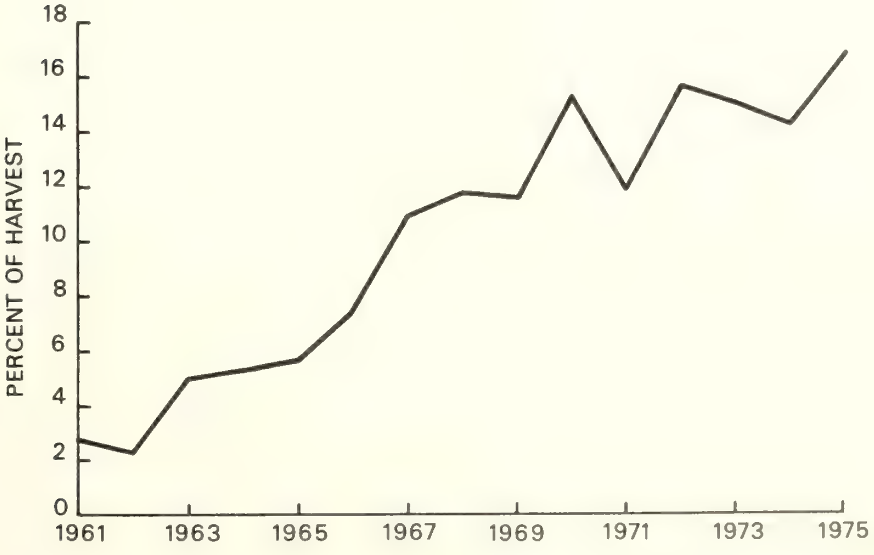

Figure 2.--Softwood log exports as a percent of timber harvest in Washington and Oregon 1961-75. Source: Ruderman (1976).

to these concerns, Alaska, Oregon, California, and Idaho implemented control measures on State-owned lands and Federal regulations were initiated to limit the export of unprocessed timber from lands managed by the U.S. Department of Agriculture Forest Service or the Bureau of Land Management of the U.S. Department of Interior.

This paper presents the main features of log export restrictions imposed by the various State and Federal agencies as well as those of British Columbia as of mid-1977. Where appropriate, some historical background will be given to provide a better perspective as to how present regulations evolved. For additional background, the reader is referred to Austin (1969).

Joint Determination by Secretaries of Agriculture and Interior

On April 16, 1968, the Secretaries of Agriculture and Interior issued joint determinations concerning log exports from National Forest and Bureau of Land Management lands in western Oregon and western Washington. These stated that a restriction on the volume of logs harvested and exported from Federal lands in unprocessed form was necessary to maintain a viable domestic wood processing industry capable of processing the sustained yield of timber from the selected areas. Authority for the action is contained in the Organic Administration Act of June 4, 1897 (16 U.S.C. 475, 551) in the case of the Secretary of Agriculture. The O and C Act of August 28, 1937 (50 Stat. 874), provided the enabling legislation for the Secretary of the Interior. The volume exported was to be limited to 350 million board feet annually to be divided between Forest Service and Bureau of Land Management lands in the affected areas.[1] An accompanying plan provided operating and administrative details including the allocation of the limited or "exempt" volume among selected National Forests, the definition of processed products, and exceptions to be allowed such as Port-Orford-cedar which was declared surplus to domestic needs.[2]

This program was to be in effect until June 30, 1969, at which time it would be subject to review and possible renewal. It was superseded on January 1, 1969 by the Morse Amendment.

Morse Amendment

Following hearings in 1968, Senator Wayne Morse proposed Part IV of the Foreign Assistance Act of October 8, 1968, (82 Stat. 966) commonly called the Morse Amendment. Taking effect January 1, 1969, the Morse Amendment legislated the same log export quota that had been initiated by the joint determination by the Secretaries of Agriculture and Interior. The area under control, however, was extended to include all Federal lands west of the 100th meridian (a line running through the middle of North Dakota through central Texas) including Federal lands in Alaska. The 350 million board feet of exempted volume was jointly allocated to areas administered by the Forest Service or the Bureau of Land Management in Washington, Oregon, and California. The volumes subsequently exported, however, were below the allocated volumes (Austin 1973)

The Morse Amendment also authorized the Secretaries of Agriculture and Interior to issue rules and regulations to prevent the substitution of Federal timber for non-Federal timber which had been exported. In 1969 the Forest Service and Bureau of Land Management began exploring ways and means of implementing the substitution clause including the holding of a joint public advisory hearing at Portland, Oregon on September 26, 1969, to obtain comment on a proposed plan. No further action was taken, however.

The Morse Amendment further permitted the Secretaries of Agriculture and Interior to declare certain amounts of unprocessed timber as surplus to domestic needs and thus eligible for export. Such a determination could only be made after the holding of a public hearing to seek advice and counsel as to quantities, species, and grades that might be in surplus. Following public hearings at Portland, Oregon on December 6, 1968, Alaska-cedar was determined to be surplus to domestic needs from Forest Service and Bureau of Land Management lands in Washington, Oregon, and California.

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[1] A determination by the Secretary of Agriculture concerning primary processing of timber from National Forests of the Pacific Northwest (unpublished). Specified in the Secretary of Agriculture April 16, 1968 memorandum to the Chief of the Forest Service.

[2] Plan for requiring domestic primary manufacturing of logs from National Forest land in the Pacific Northwest (unpublished). Response to the April 16, 1968 memorandum of the Secretary of Agriculture.

Port-Orford-cedar was also found to be in surplus with the exception of small volumes of select salvage old-growth material which was deemed necessary for the manufacture of arrow shafts and thus ineligible for export. Other than this minor exception, Port-Orford-cedar may be exported in unprocessed form.

A similar hearing at Juneau, Alaska, on May 5, 1969, established that Alaska-cedar and western redcedar were surplus species from Federal lands in Alaska. Consequently these species were freely exportable from these Federal lands and the resulting volumes were in addition to the 350 million board feet of exempted volume.

The Morse Amendment had an expiration date of December 31, 1971. It was extended for an additional 2 years to December 31, 1973, by an amendment to the Housing and Urban Development Act of 1970 (84 Stat. 1817).

Appropriations Rider

In 1972, a combination of factors including an unprecedented housing boom both here and in Japan led to an extremely tight supply situation for west coast softwood logs. Hearings were held in 1972 and 1973; and several proposals to limit log and/or lumber exports, including those from private lands, were introduced in Congress.

Finally, in October of 1973, Congress attached a rider to the Department of the Interior and Related Agencies Appropriation Act which in effect initiated a complete ban on the export of unprocessed timber from Federal lands in the West. The General Provision attached to the fiscal year 1974 appropriations bill stated:

> No part of any appropriation under this Act shall be available to the Secretaries of the Interior and Agriculture for use for any sale hereafter made of unprocessed timber from Federal lands west of the 100th meridian in the contiguous 48 States which will be exported from the United States, or which will be used as a substitute for timber from private lands which is exported by the purchaser--*Provided*, that this limitation shall not apply to specific quantities of grade and species of timber which said Secretaries determine are surplus to domestic lumber and plywood manufacturing needs.[3/]

Thus the provisions imposed by the appropriations rider were generally more restrictive than under the Morse Amendment. The appropriations rider constituted a complete export ban on Federal timber (except for those species and grades declared surplus) compared with a quota of 350 million board feet under the Morse Amendment. In addition, the language of the substitution clause was now directive whereas formerly the Secretaries were only authorized (but not directed) to enact regulations to prevent substitution. On the other hand, the appropriations rider was somewhat less restrictive in that Federal lands in Alaska were no longer included, whereas they were under terms of the Morse Amendment. As will be discussed later, however, log exports from National Forest lands in Alaska are restricted according to the terms of other legislation.

The appropriations rider has been attached to the Interior appropriations acts for each succeeding year (fiscal years 1974 through 1978) and is currently the basis for the complete ban on the export of unprocessed timber from lands administered by the Forest Service and Bureau of Land Management in the West (except Alaska).

The remainder of this section of the report will highlight recent Forest Service and Bureau of Land Management attempts to develop regulations to implement the terms of the rider to agency appropriations.

[3/] Department of the Interior and Related Agencies Appropriation Act, 1974 (P.L. 93-120, October 4, 1973), Sec. 301.

FOREST SERVICE

On October 26, 1973, the Forest Service published proposed regulations in the Federal Register and, based on comments received, Title 36 of the Code of Federal Regulations was revised to incorporate regulations prohibiting the export of unprocessed National Forest timber or its substitution for exported private timber. The effective date was March 13, 1974. These are the regulations currently in force; the more important provisions are as follows:[4]

1. *Unprocessed timber* does not include pulp (utility) grade logs and Douglas-fir special cull logs. In addition, the following are defined as having been processed and thus eligible for export:

   a. lumber and construction timber sawn on four sides,
   b. chips, pulp and pulp products,
   c. green veneer and plywood,
   d. poles and piling cut or treated for use as such,
   e. cants cut for remanufacture, 8-3/4 inches in thickness or less.

2. *Substitution* of public timber for private timber which is exported occurs "when with respect to historic levels, (1) the purchaser continues to export and increases his purchase of National Forest timber, or (2) the purchase of National Forest timber continues while the purchaser increases his export of unprocessed timber from private lands tributary to the plant for which National Forest timber covered by a specific contract is expected to be delivered."[5]

   "Private lands" does not include lands managed by other Federal or State agencies or lands held in trust by the United States for Indians. The term "historic level" means 110 percent of the average annual volume of Federal timber purchased or exported during the calendar years 1971, 1972, and 1973. Thus, an individual is substituting National Forest timber for exported private timber if for a calendar year, and with reference to his historic level, he increases his export of private timber while continuing to purchase National Forest timber in a particular timbershed *or* he continues to export and increases his purchase of National Forest timber. Also, an increase in export of private timber is prohibited by contractual terms during any calendar year in which National Forest timber is harvested, if the National Forest timber was purchased pursuant to the above limitation.

3. *Surplus species* of timber are not bound by the regulations and are freely exportable. At present Port-Orford-cedar and Alaska-cedar are classified as surplus; following public hearings, the Secretary of Agriculture may declare additional species, grades, or quantities of timber as surplus to domestic needs. In addition, sales having an appraised value of less than $2,000 are not bound by the export or substitution regulations.

The above regulations took effect in March of 1974 and have had only minor modifications since that time. In October 1975, the Forest Service responded to a request from a timber owner in the lower Columbia River area and solicited comments on the possibility of holding a public hearing to determine if specific quantities of western hemlock might be found surplus to domestic needs. The majority of the respondents opposed such a hearing and, as a result, no further consideration was given to adding western hemlock to the list of surplus species.

In April 1976, the Forest Service tried to standardize procedures for the holding of a public hearing to consider the question of surplus species. Two alternatives were offered.

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[4] Code of Federal Regulations, Title 36, Chapter II, Part 223.10.

[5] Code of Federal Regulations, Title 36, Chapter II, Part 223.10(e).

One alternative required that proponents submit a thoroughly documented request supporting the conclusion that a particular species or grade is surplus. The Secretary would then file notice in the Federal Register asking for comments. Based on these, a decision would be made on the necessity for holding a public hearing.

The second alternative would involve an analysis of no-bid sales to determine which species or species groups were involved. Public hearings would be scheduled if the analysis indicated a surplus.

Public response favored the first alternative. Therefore, the Forest Service will use this procedure to determine if a class of material is surplus to domestic needs. No regulation change was required and none was made.

Also in April 1976, in response to a request by the House Committee on Appropriations, the Forest Service solicited comments on a proposed rule change governing the distinction between processed and unprocessed timber. Three alternative definitions were offered which bracketed the current definition of cants. One alternative would require that all material be completely sawn on four sides to qualify as processed. A second alternative would allow a limited amount of wane as permitted under "Export R" rules, of the Pacific Lumber Inspection Bureau (1971), and the third alternative would permit export of cants of any thickness. The first two alternatives would in effect eliminate the export of "waney" cants whereas the third is less restrictive than current practice.

The response favored continuance of the current definition; consequently, there are no plans for further efforts to revise the definitions of cants. A cant 8-3/4 inches in thickness or less meets current processing requirements.

BUREAU OF LAND MANAGEMENT

On June 6, 1975, the Federal Register contained notice that the Bureau of Land Management intended to amend the relevant parts of Title 43 of the Code of Federal Regulations to conform with the appropriations rider forbidding the export or substitution of Federal timber. Final regulations were published the following March 26, with an effective date of April 1, 1976. Subject to a minor amendment noted below, these regulations are currently in effect. The more important provisions are as follows:[6]

1. *Unprocessed timber* includes any logs except those of utility grade or below, split or round bolts not processed and suitable for end product use and cants or squares to be remanufactured exceeding 8-3/4 inches in thickness. The maximum size of an acceptable cant was simply a clarification of the earlier definition which described them as a "nominal" 8 inches which meant they could range up to 8-3/4 inches in size. The current definition of unprocessed timber is thus the same as that adopted by the Forest Service.

2. *Substitution* was defined as "the purchase of a greater volume of Federal timber by an individual purchaser than has been his historic pattern within twelve (12) months of the sale of export by the same purchaser of a greater volume of his private timber than has been his historic pattern during the preceding twelve (12) months, exclusive of Federal timber purchased by negotiated sale for right-of-way purposes."[7]

   This means that a purchaser is substituting Federal timber for private exported timber if, with respect to his historical pattern, he increases *both* his purchase of Federal timber and export of private timber. His historical pattern is established from the date of his last export sale and includes the volume of Federal timber purchased and the volume of private timber exported for the 12-month period prior to this date. Substitution is determined by monitoring his purchase and export activities for the 12-month period following the above date. For example, assume that a purchaser's last export sale was June 1, 1977. His purchase and export activity for the period June 1, 1976 to June 1, 1977, thus establishes his historical pattern. Assume further that his purchase of Federal timber this period was 100 million board feet and his export sales totaled 40 million board feet. Substitution could then be illustrated by the activity over the succeeding 12-month period (June 1, 1977 to June 1, 1978).

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[6] Code of Federal Regulations, Title 43, Chapter II, Parts 5400, 5420, and 5450.

[7] Code of Federal Regulations, Title 43, Chapter II, Part 5400.0-5(n).

	Federal timber purchases	Private timber exports	Substitution
	- - Million board feet - -		
Historical pattern (6/1/76 - 6/1/77)	100	40	--
Purchaser activity	100	40	No
at various levels	110	40	No
(6/1/77 - 6/1/78)	100	50	No
	110	50	Yes

During subsequent implementation of the substitutuion regulations, the Bureau of Land Management decided that further clarification of the area under consideration for administering the substitution clause was required. Since about 95 percent of Bureau of Land Management timber harvest originates in western Oregon, it was thought that this adequately defined the market area. The Agency subsequently decided that the area under consideration should be more closely tied to utilization facilities; and in August 1976, the definition of substitution was amended accordingly. The current Bureau of Land Management definition of substitution is thus:

> (1) The purchase of a greater volume of Federal timber by an individual purchaser than has been his historical pattern within twelve (12) months of the sale of export by the same purchaser of a greater volume of his private timber than has been his historic pattern during the preceding twelve (12) months, exclusive of Federal timber purchased by negotiated sale for right-of-way purposes, and (2) the increase of both the purchase of Federal timber and export of timber from private lands tributary to the plant for which Bureau of Land Management timber covered by a specific contract is expected to be delivered.[8/]

The first part of the definition pertains to an individual's purchase and export activity relative to his historical pattern; the second part establishes the market area. "Federal timber" means timber sold by the Bureau of Land Management. Timber sold for right-of-way purposes is subject to the export ban but not the substitution restrictions. The Bureau of Land Management definition of marketing areas is thus identical to that used by the Forest Service. The Forest Service definition of substitution is more restrictive, however, in that a continuation in purchases or exports with an increase in either constitutes substitution whereas the Bureau of Land Management definition specifies an increase in both purchases and exports.

3. *Surplus species* may be designated by the Secretary of the Interior as available for export following public hearings authorized by the Director of the Bureau of Land Management to seek advice and counsel as to the specific grades and species that might be surplus to domestic needs. Port-Orford-cedar and Alaska-cedar have been so designated.

National Forests in Alaska

Federal lands in Alaska are not included under the provisions of the appropriations rider pertaining to log exports; the provisions apply only to the contiguous 48 States. Since 1928, however, the Forest Service has limited the export of unprocess logs from National Forests in Alaska under general authority granted by the Organic Administration Act of June 4, 1897 (16 U.S. 475, 551).

Forest Service policy on limiting the export of logs was established by way of

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[8/] Code of Federal Regulations, Title 43, Chapter II, Part 5400.0-5(n).

the Secretary's approval of a memorandum from W. B. Greeley, Chief Forester, dated January 6, 1928. Subsequent regulations stated that no timber harvested from National Forests in Alaska may be exported in unprocessed form from Alaska without the prior consent of the Regional Forester. The primary processing requirement was imposed to insure the development and continued existence of adequate wood processing capacity essential for the utilization of timber from the State's National Forests. This constraint is more restrictive than those commonly in effect elsewhere, in that it not only forbids export of unprocessed timber from Alaska to overseas markets but also to domestic markets in other States.

Although timber from National Forests in Alaska may be exported with the consent of the Regional Forester, the regulations impose other restrictive factors that he must consider in making such a decision. Among other things, he must consider whether such export will:

> (1) permit a more complete utilization of material on areas being logged primarily for products for local manufacture, (2) prevent loss or serious deterioration of logs unsalable locally because of an unforeseen loss of market, (3) permit the salvage of timber damaged by wind, insects, or fire, (4) bring into use a minor species of little importance to local industrial development, or (5) provide material required to meet national emergencies or to meet urgent and unusual needs of the Nation.[9]

Species surplus to domestic needs and otherwise meeting any of these requirements are eligible for export following approval by the Regional Forester on a case-by-case basis.

Federal lands in Alaska did not share in the exempted volume granted under the provisions of the Morse Amendment. Following a public hearing on May 5, 1969, in Juneau, western redcedar and Alaska-cedar were, however, declared surplus to domestic needs and thus eligible for export; annual exports from National Forest lands have averaged about 9 million board feet since then. In 1975, 13.5 million board feet of logs were exported and of this 58 percent was Alaska-cedar, the remainder western redcedar.[10]

By mid-1976 there were indications that surpluses of western redcedar were decreasing. Before considering export application, the Forest Service began to require proof that logs had been first offered for sale to domestic manufacturers. Following a public hearing, the Forest Service on November 18, 1976, established that western redcedar was no longer in surplus and thus would be exportable only if the processing requirements were met. This decision was appealed and subsequently reversed on September 26, 1977, for the area included in the long-term sale to the Ketchikan Pulp Company. Other than this exception, western redcedar may not be exported in unprocessed form from National Forest lands in Alaska. Alaska-cedar remains in surplus and thus exportable with permit.

The definition of primary manufacture for timber from National Forest sales in Alaska is the same as that employed on National Forest lands elsewhere. Cants not thicker than 8-3/4 inches meet the definition of primary manufacture. Green veneer and poles and piling are considered manufactured and thus eligible for export. Primary manufacture in the case of pulp manufacture means the breakdown process to that point where the wood fibers have been separated.

As a result of regulations published on December 5, 1977, chips are also considered as receiving primary manufacture. Formerly, chips could be exported only if manufactured from logging and milling waste, but not from roundwood. The objective of the revised regulation was to provide firms in Alaska with marketing alternatives for logs which are not suitable for sawing.

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[9] Code of Federal Regulations, Title 36, Part 223.10(i).

[10] Information provided by Office of Regional Forester.

Bureau of Land Management Lands in Alaska

The Bureau of Land Management does not have an ongoing timber sale program in Alaska pending settlement of the Alaska Native Claims Settlement Act of 1971 (P.L. 92-203). The few small sales that are made are only for local, domestic needs. Consequently, no regulations have been written pertaining to the export of logs from Bureau of Land Management lands.

Bureau of Indian Affairs

The Department of the Interior ban on log exports does not apply to lands managed on behalf of the Indians. Individual reservations may, however, impose such restrictions should they wish. As far as is known, none exists at this time.

There is one area of land managed on behalf of the Indians from which unprocessed timber may not be exported. This is an area of 61,360 acres known as the "McQuinn Strip," which borders on the north and west sides of the Warm Springs Reservation of Oregon. Ownership of the strip was disputed for many years because of an earlier contested survey. Finally, in 1972, title to the former Federal land which formed parts of two National Forests was ceded to the Confederated Tribes of the Warm Springs Reservation of Oregon.

The act[11/] which transferred title to the land contained language which in essence was designed to retain existing marketing patterns for timber from the Strip until January 1, 1992. Among other things, the act specified that timber from the Strip must be designated for primary manufacture in the United States. In administering the act, the Bureau of Indian Affairs has adopted the Forest Service definition of processed versus unprocessed timber to define primary manufactured items, i.e., lumber, chips or pulp, green veneer, poles and piling, or cants 8-3/4 inches in thickness or less.

State of Alaska

Since 1960, the State of Alaska has had primary manufacturing requirements on timber flowing from State-managed lands and destined for export from the State. Subject to approval of the Commissioner of Natural Resources, limited amounts of round logs (except spruce and hemlock) may be exported for experimental purposes such as to pilot test a new product. Other than this minor exception, unprocessed logs may not be exported.

Cants are considered to have received primary manufacture when sawed to a maximum thickness of 12 inches. Timber cut thicker than 12 inches must be squared on four sides with a wane allowance of up to one-third of each dimension (thickness and width). Thus, squares of any thickness are considered to have received primary manufacture.

The most recent Policy Statement on Primary Manufacture, issued in May 1974, was intended to ease restrictions pertaining to the export of chips.[12/] Prior to that time chips were considered to have received primary manufacture and thus were eligible for export only when processed from logging or mill residues having no local market. The policy initiated in 1974 permitted the export of chips produced from surplus roundwood from interior Alaska.[13/] As before, chips from southeast Alaska may be exported only when produced from logging or mill residues.

Primary processing definitions for other products are similar to those for National Forest lands. In the case of pulp manufacture, primary processing is the point at which the fibers have been separated (other than the special case for chips discussed above). Green veneer and poles and piling meet primary processing requirements and are permissible for export.

State of Washington

The State of Washington imposes no restrictions on export of timber from lands managed by the State. The most recent referendum was in 1968 when State voters

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[11/] Act of September 21, 1972 (P.L. 92-427, S. 2969).

[12/] State of Alaska. Policy Statement on Primary Manufacture, May 7, 1974. Timber Sale Regulations, Section 76-130.

[13/] Areas west of 141° longitude.

defeated Initiative Measure No. 32 which would have required that all timber from State-managed lands receive primary manufacture within the State. In 1974, about 22 percent of the logs shipped by log export operations within the State originated from State-managed lands (Bergvall et al. 1975).

State of Oregon

By an emergency act passed in 1963, the State of Oregon determined that all timber sold by the State or any of its political subdivisions must receive primary processing in the United States unless the State Department of Forestry has granted an export permit.[14] Primary processing was defined by the act as "that stage of manufacture next beyond the log form of said timber."[15] Port-Orford-cedar was exempted from the regulation.

The State Forester is empowered to issue an export permit if, after public hearings, the applicant has demonstrated that the timber is currently in log form and that there is no economic domestic market for the timber. The applicant must in good faith solicit offers from domestic processors within economic transportation distance, and show that such offers do not provide a profit above the minimum stumpage prices for the sale allowing for the costs of logging and transporting the logs to their current site. The State Forester was previously required to obtain the advice of an Advisory Committee on Foreign Processing, but this committee was abolished by the 1977 Oregon Legislature.

Apparently the effect, if not the intent, of the regulations has been essentially a total ban on the export of logs from State-managed lands. Since the regulations went into effect in 1963, only 10 applications for export permits were received by the Forestry Department and of these only three were granted.[16] Total volume for the three permits that were granted was less than 2 million board feet.

State of California

Through regulations promulgated in 1974, the State of California directed that unprocessed timber from State-managed forests shall not be sold either directly or indirectly to a primary manufacturer located outside the United States.[17] Timber was deemed to have received primary manufacture when it was sawn on four sides and did not exceed 4 inches by 12 inches.

In addition to forbidding the foreign export of unprocessed timber from State-managed forests, the regulations further specified that State timber could not be substituted for timber that was exported from private lands.[18] "Substitution" in this case means the replacement of State timber for unprocessed timber which is exported from lands owned or under the control of the purchaser within California and located no more than 200 miles from the sale boundary from where the State timber was removed. Purchasers of State timber are required to execute an agreement with the State Forester to this effect as a condition of sale. Furthermore, the purchaser must notify the State Forester of all locations of State timber until such time as the timber has received primary processing. Should the timber be resold prior to primary processing, the same substitution regulations are to be imposed on the new purchaser.

States of Idaho and Montana

Small volumes of softwood logs normally flow from the Montana Customs District into Canada each year. The Montana Customs District includes all ports in Montana and Idaho. Montana imposes no restrictions on the export of unprocessed timber; Idaho does.

State of Idaho restrictions on the export of unprocessed timber cut from

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[14] State of Oregon. Sale and processing State-owned timber. Chapter 298, Oregon Laws 1963.

[15] Ibid., ORS 526.805.

[16] Information provided by Office of State Forester.

[17] State of California. Public resources code, Section 4650.1.

[18] State of California. Administrative code, Sections 1510-1521.

State-managed lands were tied to the original timber sale authority granted to the State Board of Land Commissioners. When granted timber sale authority, the Board was required to prescribe that timber cut from lands managed by the State must be manufactured into lumber or timber products within the State.[19] The authority further specified that the sale of State timber for the manufacture of wood pulp was excepted from this provision.

Subsequent rulings have affirmed the provision that State timber must receive primary manufacture before it may be exported from the State. Unpeeled cedar poles and rough, green lumber have been classified as manufactured and are eligible for export.[20] Cants may be of any size and may be exported out of State provided they are not destined for subsequent remanufacture within facilities of the *same* company. Cants may be exported and sold to *another* company for subsequent remanufacture.

British Columbia

In British Columbia, the Provincial and Federal governments share control over log exports; the Provincial government has authority over its natural resources, whereas the Federal government has jurisdiction over international trade. In practice, the two cooperate to insure that essentially all timber cut within the Province is subject to the same export controls.

Provincial control over log exports dates from March 12, 1906, with the passage of the Forest Act.[21] Part X of the Act stipulates that all timber cut on lands subject to Provincial control shall be used in the Province or manufactured in the Province. Lands under Provincial control include all Crown lands at the time of the passage of the Act as well as all lands granted after March 12, 1906.

Federal authority to control exports is contained in the Export and Import Permits Act[22] and is extended to all log exports from the Province, even those from private lands. The Federal government, however, has, in essence, delegated log export control authority to the Province in the case of Provincial lands while retaining control over all remaining lands. The remaining lands include Federal lands, such as Indian reserves, and lands Crown-granted before 1906 which include the bulk of the private lands. Although the original intention of the Provincial and Federal controls varied, recent (1974) amendments to the Export and Import Permits Act have brought Federal objectives into conformance with those of the Province. The expressed objective of export control by both levels of government is now the promotion of natural resource manufacturing in Canada (Royal Commission on Forest Resources 1976).

Controls are implemented by prohibiting export of any unprocessed timber except that authorized under individual permits issued by the Provincial Lieutenant Governor in Council, and by the Federal Minister of Industry, Trade, and Commerce. Unprocessed timber includes that not meeting wane limitations as permitted on No. 3 common (utility) lumber under the Export "R" list (Pacific Lumber Inspection Bureau 1971). Chips also must receive permit for export.

The Provincial Lieutenant Governor in Council and the Federal Minister of Industry, Trade, and Commerce are advised on log export applications by the Log Export Advisory Committee which consists of members of various industry groups and the relevant government official who serves as chairman. The Committee actually serves a dual purpose: To advise on permit applications subject to Provincial control and to advise on permits subject to Federal purview.

To render an affirmative decision, the Log Export Advisory Committee must establish the fact that the logs in question are surplus to the needs of domestic mills. To establish this fact, the applicant must advertise his logs according to specified procedures, following which he submits a formal application. Although the Log Export Advisory Committee has only an advisory role, its recommendations are generally adopted by the Provincial Cabinet and/or the Federal Minister of Industry, Trade, and Commerce.

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[19] State of Idaho. Idaho code, Section 58-403.

[20] Information provided by Idaho Department of Lands.

[21] Now called the Department of Forests Act, S.B.C. 1960, c 153, as amended.

[22] Export and Imports Permit Act, R.S.C. 1970, C. E-17, as amended.

The Chip Export Advisory Committee functions in a parallel fashion to the Log Export Advisory Committee and advises on export applications for wood residues. The committee is chaired by a member of the Council of Forest Industries, an industry association, and is composed of industry, producer, and consumer groups with governmental officials acting as observers. As with the case of log export applications, the committee must determine if an application for chip export represents supplies surplus to domestic needs. The recommendations of the Chip Export Advisory Committee are generally accepted by the Provincial Minister and Federal approval is routinely granted on top of Provincial approval.

In 1975, log exports totaled 150 thousand cunits or less than 1 percent of total harvest within the Province (Government of British Columbia, Forest Service 1976). Of this, 51 percent was exported under permit granted by the Provincial and Federal governments; the remainder was exported under permit granted solely by the Federal government.

TIMBER TAX

Exporters of timber or chips who have been granted permits subject to Provincial controls are also subject to a "timber tax" levied on the products. The level of the tax is established by the Lieutenant-Governor with the advice of the Executive Council and the Minister of Forests. By an order dated March 3, 1977, the levy on chips of $1.50 per bone dry unit was deleted. Structured tax rates employed for logs have, however, been essentially the same since May 1974. They include $2 per cunit for low-grade pulpwood, $5 per cunit for cottonwood, $40 per cunit for cypress, and $10 per cunit for all other species (Royal Commission on Forest Resources 1976).

Discussion

This survey indicates that fairly rigorous controls are exercised on log exports from public lands in the west coast area. As a result of combined Federal and State regulations in Alaska and the almost complete absence of private ownership of forest land, virtually all timber harvested in that State is subject to export regulations. A similar situation exists in the Province of British Columbia where all export of timber is subject to the approval of the Dominion Government.

In the remaining coastal States the proportion of total harvest affected by State or Federal export regulations varies somewhat. In the State of Washington only timber from National Forest and Bureau of Land Management lands is prohibited from export (no controls are imposed on State-managed lands). Together these accounted for less than 20 percent of the total harvest in 1975 (table 1). In California, the proportion of total harvest prohibited from export was about 37 percent while in Oregon, National Forest, Bureau of Land Management, some Indian lands, and State-managed lands were included which together supplied nearly half of the State harvest. For the combined three-State area, slightly over one-third of the 1975 timber harvest was directly prohibited from export by either Federal or State controls. An even larger, but unknown, proportion of the harvest is affected when the possible impacts of the substitution regulations on private initiatives are considered. A private individual or company might be reluctant to export its timber if it jeopardized its potential supply of public timber.

No attempt will be made here to analyze the domestic effects of these constraints. Some analysis of the effect of softwood log exports on domestic employment has been made by Darr (1975), and Haynes (1976) has examined the price impacts of log export restrictions on domestic lumber and stumpage markets.

Further analysis will be required to assess the probable impact of these controls on the quantity of timber actually entering the export trade. The language of a restriction can be quite strict; but when related to the affected areas, it might have little impact on the quantity of timber available for export or the quantity actually exported. This would depend on additional aspects of supply such as total volumes affected, location, species, and grades as well as on the overriding importance of the characteristics of both domestic and foreign demand.

Table 1--*Proportion of total timber harvest prohibited from export by direct Federal or State controls for Washington, Oregon, and California 1975*

State	Total timber harvest by State	Portion of total harvest prohibited from export by Federal controls		Portion of total harvest prohibited from export by State controls		Portion of total harvest prohibited from export by Federal or State controls	
	-------- million board feet -----		percent	million board feet	percent	million board feet	percent
Washington	6,185	1,099	17.8	--	--	1,099	17.8
Oregon	7,371	3,305	44.8	160	2.2	3,465	47.0
California	4,334	1,569	36.2	35	0.8	1,604	37.0
Total	17,890	5,973	33.4	195	1.1	6,168	34.5

Source: Ruderman (1976)
California Division of Forestry (1976)
Lloyd (1976, 1977)

Table 2 provides a comparison of some of the more important provisions of the log export and substitution restrictions for Federal, State, and Provincial jurisdictions.

Table 2--*Comparison of log export restrictions*

Geographic area	Lands affected	General limitations	Exemptions	Definition of primary processing	Definition of substitution
areas west of th meridian in tiguous 48 States.	National Forests	No export of unprocessed National Forest timber nor substitution for timber exported from private lands.	Port-Orford-cedar, Alaska cedar. Sales having appraised value less than $2,000.	Cants 8-3/4 inches in thickness or less, lumber and squares, chips & pulp, green veneer and plywood, poles and piling.	With respect to historical levels, the purchaser continues to export and increases purchase of National Forest timber, or increases export of private timber while continuing purchase or harvest of National Forest timber.
areas west of th meridian in tiguous 48 States.	Bureau of Land Management	No export of unprocessed BLM timber nor substitution for exported private timber.	Negotiated right-of-way timber sales. Port-Orford-cedar. Alaska-cedar.	Cants and squares 8-3/4 inches in thickness or less, lumber, chips and pulp, green veneer and plywood, poles and piling.	With respect to historical pattern both purchase of BLM timber and export of private timber increase.
ska	National Forests	No export of unprocessed timber from State.	Alaska-cedar Western redcedar on long-term sale to Ketchikan Pulp Company.	Cants 8-3/4 inches in thickness or less, green veneer, poles and piling, pulp, and chips.	NA
ska	State of Alaska	No export of unprocessed timber from State.	With prior approval, small volumes of all species except spruce and hemlock may be exported for experimental purposes.	Cants 12 inches or less in thickness; squares any thickness with one-third each dimension (thickness and width) allowed in wane; chips from logging and mill waste; chips from roundwood in interior Alaska.	NA
gon	State of Oregon	Export of unprocessed timber by permit only based on unavailability of domestic markets.	Port-Orford-cedar	That stage of manufacture next beyond the log form.	NA
gon	McQuinn Strip portion of Warm Springs Reservation	Until January 1, 1992, timber from the McQuinn Strip must be designated for primary manufacture in the U.S.	None	Lumber, chips or pulp, green veneer, poles and piling cants 8-3/4 inches in thickness or less.	NA
ifornia	State of California	No export of unprocessed timber nor substitution of State timber for timber exported from private lands.	None	Squares not exceeding 4 inches X 12 inches	Replacement of State timber for timber exported from private land within 200 miles of State timber sale area.
ho	State of Idaho	State timber must receive primary manufacture within State	Pulpwood	Cants provided not subsequently remanufactured out-of-State by same firm; lumber, poles.	NA
itish Columbia	All lands	Export of unprocessed timber or chips from Province only by permit based on surplus. Export tax on Provincial logs.	None	Lumber meeting wane requirements for No. 3 Common (Utility) under Export "R" list.	NA

- not applicable.

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1978

PROCEEDINGS OF

THE WORKSHOP ON NONGAME BIRD HABITAT MANAGEMENT IN THE CONIFEROUS FORESTS OF THE WESTERN UNITED STATES

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RICHARD M. De GRAAF

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

The Technical Coordinator for this proceedings was Richard M. DeGraff, Wildlife Biologist, Northeastern Forest Experiment Station, University of Massachusetts, Amherst.

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PROCEEDINGS OF THE WORKSHOP ON NONGAME BIRD HABITAT MANAGEMENT IN THE CONIFEROUS FORESTS OF THE WESTERN UNITED STATES

FEBRUARY 7-9, 1977

Portland, Oregon

RICHARD M. DeGRAAF

Technical Coordinator

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
Forest Service U.S. Department of Agriculture

PREFACE

Nongame birds are often neglected natural and recreational resources. Managers know that birds eat insects and seeds, and have other functions in ecosystems, and that many people enjoy birding. But generally nongame birds have not been seriously considered in land management decisions. Scientists, on the other hand, have long studied birds as an occupation or avocation, but they have seldom related their studies to land management activities. The recent increase in environmental awareness and the dramatic changes in patterns of wildlife-related recreation produced the symposium, "Management of Forest and Range Habitats for Nongame Birds," held in Tucson, Arizona, May 6-9, 1975. That symposium initiated a dialogue between resource managers and avian ecologists. This is the first of a planned series of regional workshops designed to follow-up the Tucson symposium in order to present the principles and techniques of nongame bird management in detail to managers at all levels.

The views expressed are those of the participants and are not necessarily those of the U.S. Department of Agriculture.

The following organizations sponsored this workshop:

- Forest Service, USDA
- Soil Conservation Service, USDA
- Bureau of Land Management, USDI
- Fish and Wildlife Service, USDI
- National Wildlife Federation
- The Wildlife Society
- Wildlife Management Institute
- National Audubon Society
- International Association of Wildlife Agencies

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ECOSYSTEMS, HABITATS, WILDLIFE, AND MANAGEMENT[1]

Chris Maser[2] and Jack Ward Thomas[3]

Abstract.--We elucidate the long-term biological and economic inadequacy of the single-use concept in land management and define and illustrate the principles of holistic, ecosystem management. The common denominator for all living things is a habitat in which to live. Habitats are measurable and can be managed. Our job is to construct a sound foundation of biologically and economically sound guidelines for land management. Our responsibility is to the future as well as the present.

INTRODUCTION

> *There are some who can live without wild things and some who cannot.... Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher 'standard of living' is worth its cost in things natural, wild, and free. For us..., the opportunity to see geese...and the chance to find a pasque-flower is a right as inalienable as free speech.... The whole conflict thus boils down to a question of degree...a law of diminishing returns in progress....* (Leopold 1949)

LAND MANAGEMENT--THE CONCEPT

Management of our land and wildlife has been, and often still is, single-use oriented. However, we now have reached the stage in development of knowledge where the single-use concept is no longer valid or viable in land management. We can no longer afford a comfortably oversimplified economic view of our land and resources as attested by the passage of such laws as the Multiple-Use Sustained-Yield Act, the Rare and Endangered Species Act, the Environmental Policy Act, and the Forest Policy Act. Therefore, land management must evolve toward total ecosystem management, not only convenient fragments thereof.

> *We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect. There is no other way for land to survive the impact of mechanized man, nor for us to reap from it the esthetic harvest it is capable, under science, of contributing to culture.*
>
> *That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics. That land yields a cultural harvest is a fact long known, but latterly often forgotten.* (Leopold 1949)

"GETTING A HANDLE" ON ECOSYSTEMS

One of our problems today is "getting a handle" on the concept of an ecosystem. One way to understand an ecosystem is to think of it as if it were a theatrical production, with you sitting in the audience. Consider the stage to be the land base (a piece of real estate). The props are the plant communities and successional stages which will change, within appropriate limits, as the scenes of the play unfold. The animals are the actors and the most mobile. As a play is governed by a script, ecosystems are governed by biological principles.

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[1] Paper presented at the workshop on Nongame Bird Habitat Management in Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

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The same principles govern all ecosystems; they differ only in the degree of magnitude with which they affect a particular system. Water, for example, is a limiting factor in the distribution of some animals in a hot, dry desert, but water is also a limiting factor in the distribution of some animals along a humid coast. However, access to water limits the distribution of more animals in a desert than it does along a humid coast.

Within accepted formats, scripts for plays are written by people, scripts are edited by people, final performances are directed by people, and the reviews and critiques are made by people. Script formats for land management--set by ecological understanding and by law and policy--define limits on the scripts written collectively by foresters, wildlife biologists, range specialists, and other resource personnel. These scripts are edited by the land-use planners and interpreted and directed into performances by managers. The general public will critique, often through the courts or legislative process, the entire performances. It is imperative that we understand and utilize ecosystem concepts in land management.

PLANT COMMUNITY AND SUCCESSIONAL STAGE

The term "successional stage" was coined by botanists and is generally considered in terms of plant succession, but successional stages have two components: plants and animals. Plant and animal communities are the living components of an ecosystem. These communities (different theaters) progress through a series of successional stages (like scenes in a play) from pioneering stages (the first scene) through climax stages (the final scene). As a plant successional stage changes, so does the animal successional stage. These changes should be predictable.

Wildlife respond primarily to the structure of plant communities and their successional stages. Structure results from the plant species composition and their growth forms. The greater the plant diversity the more complex the structure. The function of a plant community or successional stage is the uses that wildlife can make from it. Structural complexity dictates functional opportunities or niches for wildlife use; thus the magnitude of opportunities for wildlife use is a measure of habitat diversity which yields wildlife diversity within a plant community or stage.

THE QUESTIONS WE NEED TO ASK

One of our problems in understanding these concepts has been the way we have asked questions about them. We have asked only the questions: (1) What species of animals occur in the area? (2) How many individual animals are there? (3) What do they do there? If we are to understand plant-animal interrelationships, we should inquire: (1) Why are the species there? (2) Why do the species do what they do?

WILDLIFE AND ECONOMICS

We are often faced with the demand that wildlife's existence must be justified in dollars and cents. Albeit such justification is symptomatic of single-use orientation and ethically wrong to those who "cannot live without wild things," it is a reflection of real life and not, necessarily, all bad. We need timber harvest, livestock grazing, hunting, fishing, and the fur harvest not only because they provide products but also because they stir man's economic interest and, in the longer term, protective interest. At the present stage of human development we tend to treat callously those lands and wildlife upon which we do not place high economic value. Money is the common language of western man and is utilized by wildlife biologists, foresters, engineers, economists, etc. involved in land-use planning decisions. That is fine as far as it goes.

On the other hand, man has defined species as economically desirable, undesirable, or neutral--good, bad, or indifferent. This may be good, short-term economics; but it is very poor ecology. We must consider both direct and indirect cost/benefits of our management decisions. No longer can we afford wildlife sacrifices on the altar of cost-effectiveness nor allow wildlife scapegoats to take the blame for interrelationships that we do not fully understand.

MANAGEMENT ALTERNATIVES

The time for management decisions to be governed by emotions is past. We cannot afford the continuing polarization of "conservationists" on one hand and "economists" on the other since both extremes are dead-end streets. We need facts. Facts add up, revealing alternatives. Facts let us find middle ground with resulting flexibility. Loss of flexibility leads to loss of alternatives, and without alternatives there neither is nor can there be wise land management.

COST/BENEFITS OF MANAGEMENT

How do we manage for direct as well as indirect cost/benefits of our land and wildlife? At the most intensive level we must manage for species--not individuals. At the extensive level we must manage for habitats--not species, and for insured diversity--not single habitats.

To manage for habitats and their attendant wildlife species we must manage in terms of broad groups of similarly habitat-adapted species or "life forms." A species' habitat requirements for feeding are generally broader and more flexible than are its habitat requirements for reproduction. So if we combine all species with similar habitat requirements for feeding and habitat requirements for reproduction, we have a "life form." For example, a land manager in northeastern Oregon, for purposes of extensive land management decisions need not, in general, know the 379 species of land vertebrates; he can deal with 16 life forms (Thomas et al. 1976). With these, he has in hand the tool to judge management alternatives and consequences thereof prior to making a decision. He may choose to manage for diversified habitats in general and then, within those limits, for a specialized species.

Utilizing this life form-habitat concept, a manager can make a wise or unwise, good or bad decision with respect to wildlife, but it must be made in an arena that clearly identifies the wildlife-commodity trade offs.

HABITAT--A COMMON DENOMINATOR

The common denominator for existence of all living things is their requirements of a habitat in which to live, where: FOOD + WATER + COVER = HABITAT. Long-term survival of species--including man--dictates the necessity of proper, sound management to provide the myriad of necessary habitats. Fortunately, habitats are measurable, both qualitatively and quantitatively, and can be managed. It is imperative that we not only understand but also nurture the quality, quantity, diversity, and stability of habitats and their essential components.

Everything that we do in management is ultimately geared toward the maintenance and betterment of *our* habitat. Since man is humanitarian, man is, in a sense, the world's most important renewable resource; and for man to survive, over the long run, it is probably necessary that renewable resources be carefully husbanded. There is a developing sense that if man is to survive in a quality environment he must have a holistic, ecosystem view; but it is probably futile to expect man to ever operate in other than humanitarian terms. Yet with a broader view of self-interest, it may be possible to achieve the same ends that would evolve from the development of a more altruistic philosophy.

Our oceans, ranges, forest, and cities are not independent of one another. We cannot biologically, and dare not economically, compartmentalize land management in the narrowness of the historical single-use concept. We must, therefore, understand, accept, and apply one cardinal principle to land management. *Land management is tending toward, and ultimately must become, total ecosystem management.* In some land-use planning there is a continued tendency to conceive different product systems, i.e., a timber system, a range system, a wildlife system, a recreation system, and a water system. When conceptualized in this way, it appears possible to have dramatically more of everything simultaneously. Such results are unlikely.

Instead, we must conceive of one system that produces multiple products. There are many ramifications to timber and range management plans and procedures besides the production of wood and red meat. For example, and that is our interest in this symposium, birds must also be considered as products of such operations.

Point: Under the ecosystem or holistic concept of management we have one system that produces many simultaneous products. All products, as well as the continued well-being of the system, must be considered. Single-use planning, even with simultaneous planning for a number of single-use objectives, most emphatically is neither ecosystem nor holistic management.

LAND MANAGEMENT FOR THE FUTURE

We can no longer afford to manage solely for the present; we must manage for the future as well. We must mimic, as closely as possible, the natural, evolved, and balanced systems. We must manage for diversity of habitats (multiple use) to insure the survival of our wildlife. We must holistically view and protect, through wise management, our lands (especially such areas as wilderness, primitive areas, and refuges) as savings accounts for future generations. As populations grow, our land support base becomes increasingly important, accruing interest for all men, present and future.

LAND MANAGEMENT--OUR RESPONSIBILITY

For us..., the opportunity to see geese... and the chance to find a pasque-flower is a right as inalienable as free speech. (Leopold 1949). Whose responsibility is the welfare of our land? If one reads Leopold's "Game Management" (1933) and "A Sand County Almanac and Sketches Here and There" (1949), one may gain the impression--and rightly so--that the welfare of our land and wildlife is the responsibility of every man. But Leopold wrote these books as a professional wildlife biologist, forester, and land manager; he spoke with and of professional training, conduct, ethics, and foresight. Aldo Leopold wrote to us. It would be a sad commentary if we--the professional wildlife biologists, foresters, and land managers of today--could not have the positive impacts on the ethics of land management that Aldo Leopold, a single individual, had over 30 years ago.

LAND MANAGEMENT--A LEGACY FOR THE FUTURE

When we were children, it was our right to expect a quality environment. Now we are adults and it is no longer our right to expect; it is our responsibility to insure a quality environment for the future generations. When those generations become adult, the wise stewardship of our land becomes their responsibility. In this way our land passes from one generation to the next.

Today, the responsibility to the future is ours.

IN CONCLUSION

Our purpose is to set the stage for the symposium. Following papers deal with the various components of holistic, ecosystem management.

ACKNOWLEDGEMENTS

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THE IMPORTANCE OF BIRDS IN ECOSYSTEMS [1]

Richard M. DeGraaf [2]

Abstract.--Birds are important in forest ecosystems through their roles in energy transfer through food webs and nutrient cycling; and birds are an important recreational resource. The consumption of foliage insects probably constitutes the major functional role of birds in forests. While birds apparently cannot control insect outbreaks, the main role of birds appears to be one of acting to prevent insect outbreaks, or of dampening insect population oscillations. Birds exert the greatest influence on insect populations at endemic levels, and may thus also serve to increase the time interval between insect outbreaks.

While birds account for relatively minor parts of the standing nutrient pools of forest ecosystems, bird migration has been shown to account for 16 percent of the net phosphorous loss from a forest ecosystem.

Recreational values of birds cannot be ignored--there are millions of birdwatchers in the United States, and dollar expenditures to enjoy birds exceeds $500 million annually.

INTRODUCTION

Birds, especially migratory birds, are spectacular components of ecosystems. North American warblers, the Parulidae, literally link the tropics and the northern coniferous forests with their seasonal migrations (Odum 1971:377). What is the importance of birds in ecosystems? How do they function in ecosystems?

Bird populations are involved in the functioning of ecosystems through their roles in energy transfer through food webs, food consumption, and nutrient cycling. In speaking of ecosystems, energy flow is usually considered the most important link between bird populations and components of the environment. This linkage is of importance because it is through these energy flow pathways that food consumption patterns and predator-prey dynamics are determined (Wiens 1975). Over a range of coniferous forest stands in western Oregon in the breeding season, one percent of the avian energy flow was channelled into production, 15-16 percent was channelled into reproduction, and 13-19 percent of the seasonal total was required for thermoregulation (Wiens and Nussbaum 1975). More importantly, about 80 percent of the breeding season energy was obtained mostly from animal prey sources, usually foliage-dwelling insects. The consumption of foliage insects and seeds thus probably constitutes a major functional role of birds in ecosystems (Wiens 1975).

CONIFEROUS FORESTS

Coniferous forests, the vegetative base for this workshop, occupy about one-third of the land area of the western United States, and support a diverse and distinctive birdlife. Although it has not yet been conclusively demonstrated that birds have important regulatory roles in forest ecosystems, these are important features of birds in forest ecosystems (Shugart et al. 1975):

1. In forests, the top carnivores are predominantly birds. Thus, they concentrate toxins that move up food chains such as heavy metals and persistent pesticides. Birds are therefore a sensitive ecosystem component and indicators of effects of certain toxic substances.

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[1] Paper presented at the workshop on Nongame Bird Habitat Management in Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

[2] Research Wildlife Biologist, USDA Forest Service, NEFES, University of Massachusetts, Hilton House, Amherst, Ma. 01003.

2. Birds can have significant roles in nutrient turnover in forest ecosystems. Birds generally account for relatively small parts of the standing pool of most nutrients and biomass. But, bird migration has been found to account for about 16 percent of the net phosphorous loss in a northern hardwood ecosystem (Sturges et al. 1974).

3. Birds are generally the most mobile ecosystem components, a feature of importance to seed dispersal.

FOOD CONSUMPTION

Many studies have investigated the roles of bird populations in seed consumption and predation of defoliating insects. Foliage gleaning species (mostly warblers) and timber-drilling species (mostly woodpeckers) have received the most attention, which addressed their responses to increases in insect population levels and their potential ability to control forest pests.

Insectivorous Predators

Coniferous forests usually occur in large blocks, and timber management generally renders these forests into blocks of evenaged trees. Such forests are subject to outbreaks of insects such as the spruce budworm. Insectivorous birds, largely warblers, which feed on foliage-dwelling insects, have been studied as potentially important predators of these insect pests; and the proportions of insect populations consumed by birds has been reported for several areas. For example, it has been estimated that birds consumed 3-14 percent of black-headed budworm (Acleris variana) populations in New Brunswick (Gage et al. 1970). As much as 24 percent of the winter decline in larch casebearer (Coleophora laricella) numbers was due to birds (Sloan and Coppel 1968).

Lower values of insect consumption have been reported for the spruce budworm (Choristoneura fumiferana), ranging from 1-7 percent in Ontario (Kendeigh 1947), New Brunswick (Morris et al. 1958), and Maine (Dowden et al. 1953). The consumption values of insectivorous birds is quite variable, but in no case can birds alone be attributed with actual control of the prey density.

Bird predation of these insects, which all show irruptive population patterns, is largely density-dependent (Gage et al. 1970, Mitchell 1952) with increasing consumption of insects as their populations increase. Birds react in two ways as insect populations increase. Individual birds consume a greater proportion of the particular insect as its population increases, and some species aggregate in areas of insect outbreak. Northern three-toed, hairy and downy woodpeckers all prey upon spruce beetles (Dendroctonus obesus) which infest logging slash and windthrown spruce trees (Koplin 1969).

In Rocky Mountain forests, these three woodpecker species respond both functionally and numerically to local beetle infestations--as their populations increase, beetles constitute a greater proportion of the bird's diet. The Northern three-toed forages on recently-dead trees, and so contributes most to mortality of beetles at endemic populations. As the insect population increases to epidemic levels, all three species increase their consumption rates, so that at "pan-epidemic" levels spruce beetles are essentially the only prey taken--the magnitude of this functional response is then limited by stomach capacity (Koplin 1972).

Numerical responses of woodpeckers may have a greater impact on spruce beetle populations. Woodpeckers commonly "drift" from breeding areas during the fall, and may form aggregations as they find areas of high prey (beetle) density. In Colorado, localized beetle outbreak areas produced a fifty-fold increase in woodpecker density (Koplin 1969).

Wiens (1975) has summarized some studies of the impact of these avian responses to beetle populations. At moderate to high beetle densities, woodpeckers consume 24 to 98 percent of the beetle population (McCambridge and Knight 1972, Baldwin 1960, Koplin 1972). Consumption at endemic levels is much lower--2 to 26 percent (Koplin and Baldwin 1970).

Woodpeckers destroy about 28 percent of endemic beetle populations, and about 84 percent of epidemic beetle populations. But when beetle infestations were at pan-epidemic levels, woodpeckers destroyed 53 percent; the birds can't keep up with intense beetle populations. Potential control thus appears limited to local, moderate insect populations (Baldwin 1968).

Management implications of these responses of timber-drilling birds have been suggested (Koplin 1972). Granted, we know little about the potential management of woodpeckers for the prevention of insect outbreaks either in frequency or severity. But the dramatic numerical responses of these birds to infestation of prey insects suggest that normal food supplies could be supplemented to increase woodpecker populations in areas where outbreaks are likely--in areas with spruce beetle problems, this means areas with large numbers of felled trees from logging or wind. Tree girdling to increase secondary prey numbers may be a way to supplement normal food supplies. Whether food supplies are supplemental or not, snag removal should be avoided because snags provide nest sites, and also provide secondary prey insects, which comprise much of the only prey available (Koplin 1972).

The main role of insectivorous birds appears to be one of acting to prevent insect outbreaks, or dampening insect population oscillations, rather than one of controlling insect populations or suppressing outbreaks.

Some warbler (Bay-breasted, Blackburnian, and Tennessee) species have been shown to increase their populations in response to an outbreak of the spruce budworm (Morris et al. 1958). Warblers probably show the greatest potential for this numerical response because they are migrants (and so are not subject to the local winter limitations) and are almost entirely insectivorous foliage gleaners (thus can translate increases in prey directly to increases in production of young). This numerical response of warblers to increases in defoliating insect populations has also been reported by Otvos and Taylor (1970), Sloan and Coppel (1968), and Mitchell (1952).

Early workers (Beal 1906, 1911; Forbush 1907; McAtee 1911, 1915) documented the astounding numbers of insects that birds consume, and pointed to the role of birds in the suppression of epidemic insect populations. Now we know that, with few exceptions, insectivorous birds do not suppress insect outbreaks. Birds more likely somewhat control insects at endemic population levels, and so act to prevent outbreaks. Several studies indicate that birds help to regulate spruce budworm populations, for example, at endemic levels (Kendeigh 1947, Morris et al. 1958, Morris 1963). Similar relationships have been found between birds and the larch sawfly in isolated stands (Buckner and Turnock 1965; woodpeckers and the western pine beetle, Otvos 1965; woodpeckers and other beetles, Massey and Wygant 1973; and tits and moth larvae, Gibbs 1958, 1959).

There are a few reported cases in which birds may have reduced epidemic insect populations. Woodpeckers seemed to have such an effect on high populations of southern hardwood borers (Solomon 1969). Likewise, Knight (1958) reported a case of woodpecker control of Engelmann spruce beetles.

The increased consumption of insects has been reported from large wintering aggregations or birds in areas of insect outbreak. This phenomenon has been reported for woodpeckers (Blackford 1955, Koplin 1969, Baldwin 1960) and other species (Turcek 1948, Sloan and Coppel 1968, Coppel and Sloan 1970, Mattson et al. 1968). Woodpeckers may provide some measure of control of spruce beetles in certain situations.

The importance of birds as biological control agents has been studied in Europe more than in North America. Franz (1960) cited 229 references to support his conclusion that birds, along with bats, small mammals, microbial parasites and predatory insects help hold insect populations at endemic levels or exert some control at early stages of outbreaks. In Europe, nest boxes have been installed to increase the populations of hole-nesting insectivorous birds (Herberg 1965). This practice, which takes a rather narrow view of cavities, is common in Bavarian forests (Cole, n.d.) and in Spain where 400,000 boxes have been put over 140,000 hectares (Molina 1971).

In sum, birds function in preventing rather than in controlling insect outbreaks.

Seed Eaters

Birds have potentially important roles in coniferous forest ecosystems through consumption and dispersal of seeds, especially in recently cutover areas. Several studies have described potentially serious problems in reforestation. It has been calculated that the junco, which is probably the most numerous bird in cutover areas in Douglas-fir forests, and is the only ground-feeder which is abundant all year, can consume up to 17 percent of natural seedfall (Hagar 1960). Up to 24 percent of available conifer seeds (mostly Douglas-fir) were taken by birds and chipmunks, with most losses recurring in the spring. Wiens (1975) summarized these and other studies and observed that the opportunistic feeding habits of seed-eating birds, especially of the widely-distributed juncos, will likely attract these species to artificially seeded areas. There is probably little that we can (or should) do about avian consumption of natural seedfall--the tremendous seed production of coniferous trees has allowed these forests to regenerate through time. Artificial seeding is "setting the table" for avian and mammalian seed eaters (Noble and Shepperd 1973). This is a phenomenon we'll probably have to philosophically accept. Wiens (1975) has concluded that we don't know very much about the impact of avian seed consumption on coniferous forest ecosystems, and that the possible role of avian seed consumption in natural thinning of seedlings is unexplored.

RANGELANDS

Since this workshop is also concerned with bird habitat on rangelands in the coniferous forest region, a brief summary of the importance of birds in grassland ecosystems is appropriate. Wiens (1975) discussed several ways to look at the importance of birds in range habitats. These are predation on insects, with possible consequent effects on plant growth and nutrient loss, and recreation.

Regarding these measures of avian "importance," Wiens acknowledged that at this time we cannot define the role of birds in insect control beyond estimating the amounts of the various species consumed. However, there may be indirect effects of insect consumption on plant growth. Wiens (1975) cited work (Dyer and Bokhari in prep) that indicates that chewing insects (grasshoppers) could be important in grassland ecosystems by stimulating plants to shift photosynthetic reserves to the roots and the crown, making for potentially faster regrowth when insect feeding has ceased. Opportunistic avian feeding pressure on chewing insect populations may therefore by related to plant growth.

Another factor in avian "importance" relates to nutrient cycling. Birds consuming prey insects or seeds are ingesting nutrients as well as energy. These nutrients are stored in the bodies of birds before they are released to other ecosystem components. Some nutrients are exported from northern forest and range ecosystems over time due to the migratory habits of many species, and the higher mortality of birds on wintering grounds than on breeding grounds (Fretwell 1972).

Nutrient Cycling

A study has been conducted on the role of birds in nutrient cycling in a northern hardwoods ecosystem (Sturges et al. 1974). Animals can affect nutrient flow in two ways: by affecting input or output portions of annual nutrient budgets, or by affecting the rate of circulation of nutrients in the system.

Migratory bird species, common in northern ecosystems, may be the most effective of any animal group in removing or adding nutrients to the ecosystem. Birds removed 3.0 g. Ca/ha from the northern hardwoods study area via bird migration. Approximately 9,000 g. Ca/ha were exported in dissolved substances in stream water. Results for other nutrients are shown in table 1. The most significant nutrient loss was that of phosphorous--birds accounted for about 16 percent of the net phosphorous loss through migration. Birds also participate in the circulation of nutrients in ecosystems, but their role is small. The total avian standing crop of Ca was 6.9 g./ha. But birds probably have important roles if their rates of intake or turnover of nutrients are considered--their rates of nutrient turnover are high relative to those in the standing crops of plants. Birds redistribute nutrients at roost sites and along flight pathways.

CONCLUSION

Many studies have indicated that, in forests, a major role of birds is in the prevention of insect outbreaks, or in the dampening of insect population oscillations, which otherwise might reach epidemic levels. Recognizing this function of birds, and managing accordingly, may greatly reduce our reliance on pesticides. The take-home message is that bird's role is small but vital.

It is important to examine the place that birds occupy in the ecosystem, and especially the part they play in the transfer of energy. The components of an ecosystem are not interchangeable--a mammal cannot replace a bird, or vice versa, even if both live in the same habitat and get their energy from the same food source. Even where birds play only a modest part in the energy transfer in a forest ecosystem in comparison with other animals, their special adaptations make them the only ones which can ensure a transfer to the place which they occupy in the ecosystem. Their functional significance is thus greater than the part that they represent in the total biomass of the habitat would suggest (Dorst 1974:562).

The role of birds in nutrient cycles is less clear; and while we don't presently see a major role of birds in nutrient cycles, we

Table 1.--Maximum nutrient removal by birds compared to net annual fluxes in ecosystem nutrient budgets. (Sturges et al. 1974)

	g/ha						
	Ca	N	P	S	K	Na	Mg
Maximum removal via birds	–3.0	–3.1	–1.9	–1.8	–0.8	–0.4	–0.1
Net export of dissolved substances in stream water[a]	–9200	+3400	+10[b]	–3500	–600	–5400	–2200
Export of particulate matter (inorganic + organic) in stream water[c]	–230	–110	–12[b]	–30	–520	–250	–190

[a] From Likens et al 1971

[b] From Hobbie and Likens, *unpublished data*

[c] From Bormann et al., *unpublished data*

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frankly don't know enough yet. Birds act in concert with other consumers, all of which contribute to the functioning of ecosystems.

What other questions need to be answered along these lines? Wiens (1975) has presented some questions. We know little of the linkages between avian consumers and prey population dynamics, and how these relationships are linked to other components of ecosystems. At what levels do consumption of various prey species affect the time between insect outbreaks? At what level does seed consumption inhibit regeneration? What effects do alternative food supplies have on avian responses to insect pest populations or seed survival?

More important, we need to determine the effects of forest management block size in bird populations, and also the pattern of interspersion of habitats within a forest. The following speakers will provide further elaboration on these points.

Last, a non-biological measure of bird "importance" is their economic value. The recreational importance of birds in rangelands and forests may be difficult to measure; but it is probably quite high relative to other animal groups because of the diurnal habitat of most species, their color, song, and relative lack of nuisance attributes. Many people place high aesthetic values on birds, and we do have some measures of the recreational and economic importance of birds. The U.S. Fish and Wildlife Service estimated the number of birders at 10 million in 1965 (USDI 1970). The economic values associated with the enjoyment of nongame birds have been conservatively estimated at $500 million (DeGraaf and Payne 1975).

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THE RELATIONSHIP OF BIRDS TO HABITAT STRUCTURE - PLANT COMMUNITIES AND SUCCESSIONAL STAGES[1]

E. Charles Meslow[2]

Abstract.--Measures of bird species diversity are commonly used as indicators of community structure relationships. Diversity of vegetation and structure within a habitat allows diversity in its avian community. Managed succession in the Douglas-fir region attempts to speed regeneration and establish an even-aged monoculture of Douglas-fir for harvest at optimal size. Bird species inhabiting five seral stages of these forests are identified. Four spheres of influence where timber management conflicts with forest birds are discussed: 1) Shortening of the grass-forb and shrub stage. 2) Effect of an even-aged Douglas-fir monoculture. 3) Elimination of snags. 4) Elimination of old-growth forest.

INTRODUCTION

If we are to broadly characterize the workshop participants, the inclusive title of "Resource Manager" would be appropriate. In that capacity each of us has responsibility toward the practice of land management. Land management immediately translates to management of plant communities, with forest management most importantly related to managing succession. Succession provides a continuum of plant communities each with specific structure; it is the structure of the habitat that allows bird species and assemblages of species to exist in an area--or conversely precludes their presence.

In this presentation we will examine the relationship of birds to the plant communities which are produced via succession. The succession we will focus on is that produced by forest management directed principally at timber production in Western Oregon.

BIRD SPECIES DIVERSITY

The title of this paper has a key phrase in it: habitat structure. When an ecologist hears that phrase linked with birds, we instantly relate to the important series of avian community investigations precipitated by R. H. MacArthur's studies. MacArthur and MacArthur (1961) presented a classic paper relating bird species diversity to the layers of vegetation present (i.e., structure) in the forest community. We have now interjected another key term--bird species diversity. Bird species diversity may often be thought by some of us as simply number of species present--the more species, the more diverse. There are, in fact, many different indices of species diversity. The current most commonly used index to bird species diversity is that based on the Shannon-Wiener function (Shannon and Weaver 1963).

$$H' = -\Sigma\, p_i \log_e p_i$$

where: H' = species diversity index
p_i = decimal fraction of total individuals belonging to the i^{th} species

This index of diversity considers both the number of species involved (richness) and the equitability of their numerical distribution among the species present. A one species community has zero diversity; two species, one with 99 individuals and one with 1 individual will have a diversity of 0.056 (close to 0), while two species each with 50 individuals will have a diversity of 0.694. While most ecologists use the diversity index to express the species-numerical attributes of the avian community, Tramer (1969) has shown that H' was highly correlated (r = 0.972) with species richness alone. Therefore, the same generalizations drawn on the basis of H' values should largely evolve from simple species lists. The diversity index is not as strongly influenced by rare species as a species list and is therefore useful in comparing studies in which the sampling intensities differ.

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[1] Paper presented at the workshop on Nongame Bird Habitat Management in Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

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Measures of diversity are instructive as attempts to characterize avian community numeric/species composition in a single meaningful term. However, the management of lands for birds based only on species diversity would be a dangerous mistake. The diversity indices are impersonal--starlings substitute for flickers and the numeric index remains unchanged.

BIRDS AND HABITAT STRUCTURE

It seems obvious that as the structure of habitats become more complex opportunity is provided for additional birds to exist in the area. The complexity which is added may be in the form of layers of vegetation or structures. Structures may be of various forms and origins--snags and logs or streams with streamside banks. The addition of features allows addition of species by providing requirements previously lacking. Balda (1975) provides a review of vegetation structure and breeding bird diversity. He identifies life form of the vegetation, presence or absence of certain vegetative strata, and the height of the vegetation as a constellation of factors leading birds to select habitats. Balda also points out that much of the work to date is simply correlational in nature. It is time for more critical studies that link birds to their habitats.

FOREST SUCCESSION

Douglas-fir (Pseudotsuga menziesii) forests in Western Oregon are replaced in natural succession by western hemlock (Tsuga heterophylla) and western redcedar (Thuja plicata) climaxes. Franklin and Dyrness (1973) review successional patterns in western Oregon and Washington. Following logging and/or burning, secondary succession enters a grass-forb or weed stage of perhaps 7 years duration. The grass-forb seral stage gives way to a shrub dominated period which in turn is over-topped by tree saplings--generally Douglas-fir.

The composition and density of the seral forest stands are dependent on a variety of environmental factors. Red alder (Alnus rubra) stands often develop where disturbance has been great (Newton et al. 1968). A very common occurrence, however, is the development of dense, even-aged stands of Douglas-fir. Such stands frequently are of sufficient density to eliminate understory vegetation until mortality begins to open up the stand. Truly climax forests are rare--old-growth forests, undisturbed for 400-600 years, were once relatively common. Because of the longevity of Douglas-fir, chance occurrence of fires and windstorms historically prevented extensive development of climax western hemlock forests.

In summary, the successional pattern in the Douglas-fir region usually proceeds rapidly through grass-forb and shrub stages to a closed-canopy Douglas-fir forest. When mortality begins to open these stands, western hemlock invades and reestablishment of a characteristic understory takes place. Finally, after 400-600 years without disturbance, a climax western hemlock forest may replace the Douglas-fir.

Succession in Managed Forests

The pattern of succession just outlined is significantly altered when lands are managed for timber in the Douglas-fir region. Fire is widely used for slash removal and seed-bed preparation. Seeding or planting of genetically "superior" stock speeds the reestablishment of preferred timber species, usually Douglas-fir. Herbicide applications, fertilization, and pest control contribute to the speedy establishment of an even-aged monoculture of Douglas-fir. Stands are thinned periodically, and substandard specimens are removed at that time. Harvest occurs at optimal size. Predicted tree age at harvest seems to range from 45 to 140 years depending on site characteristics and the current optimism of the managing agency.

Because of the economic value of timber, managed succession (silviculture) rather than natural succession will be the rule for most of the Douglas-fir region. We identify four areas of concern for forest birds associated with managed succession:

1. Shortening of the grass-forb and shrub stages.
2. Effect of an even-aged Douglas-fir monoculture
3. Elimination of snags.
4. Elimination of old-growth forest.

AVIFAUNA AND SUCCESSION

Let us now examine the avifauna of the Douglas-fir forests to evaluate the potential impacts of the various modifications of succession. Unfortunately, there have been no quantitative avifaunal studies that follow through the successional stages of the Douglas-fir communities in the Pacific Northwest. What are needed are studies such as those of Johnston and Odum (1956) for the piedmont of Georgia and

Haapanen (1965) in Finland. We[3] have subjectively placed 84 breeding birds of the Douglas-fir community into five seral stages (Table 1). The assignment to seral stage was our collective estimate based on field experience; we placed some reliance on the habitat descriptions provided in standard northwest bird texts (Gabrielson and Jewett 1940, Marshall 1973, Peterson 1961, Jewett et al. 1953). Bill Mannan has recently completed a field study of bird populations in relation to forest succession in Western Oregon. His work confirmed the essentials of the list (Table 1) and added numerical data for the 60 species on his study areas.

The five stages of the Douglas-fir successional series which we recognized are: grass-forbs (1-7 years), shrub-sapling (8-15 years), second growth (16-40 years), older second growth (41-120 years) and mature (over 120 years). The age designations of the seral stages are approximate and subject to variation with site factors and management. Each species was assigned one of three ratings within each stage it was found: X) commonly present, but does not nest; XX) commonly present and nesting; XXX) nesting primarily in that seral stage (Table 1). This rating system indicates how critical a seral stage is to the species. In general, the pattern of species present follows that found by other workers (Johnston and Odum 1956, Haapanen 1965): increasing numbers of species with increasing vegetative complexity.

Note (Table 1) the importance of the second seral stage to the Douglas-fir avifauna. Here some 87 percent of the species use the shrub-sapling stage, and 48 percent nest there. Hole-nesters are represented by only four species.

Our estimates (Table 1) and studies elsewhere (Johnston and Odum 1956, Haapanen 1965) indicate decreased numbers of species in mid-successional stages (i.e., the 16-40-year-old Douglas-fir second growth). This is related to a reduction in both the complexity and the layering of the vegetation (MacArthur and MacArthur 1961).

In the fourth and fifth seral stages, fewer total species (65 and 60 vs 73) but more nesting species (54 and 49 vs 40) are present than in the second stage (Table 1). Hole nesting species make up the critical element in this disparity (14 and 15 vs 4).

IMPACT OF FOREST MANAGEMENT ON THE AVIFAUNA

Shortening Period of Early Succession

Manipulation of succession to shorten the length of the grass-forb and shrub-sapling seral stages makes good sense when managing for timber production. Shortening of this period, however, reduces the duration of relatively bird-rich seral stages (Table 1). At first, most biologists may tend to discount the significance of this effect for several reasons:

a. Forests will be harvested and there will thus always be recycling through these stages. While these stages may be shortened, they will not be eliminated.

b. Timber management seems to be tending toward shorter rotation periods. If a 50-year rotation of Douglas-fir, rather than the 100 year rotation of a few years ago, is realized, there should be twice the area in early succession stages. Overton and Hunt (1974), however, have an alternative view of the yield-rotation question.

Upon closer inspection, however, the choice of methods used to shorten these early successional stages decides the impact of this management scheme on wildlife. Use of herbicides to reduce competition of nonconifers would have drastic impacts on the carrying capacity of the area for wildlife; both numbers and species of birds will be markedly reduced because the treatment makes for a structurally more simple habitat.

Management for an Even-Aged Monoculture

The terms "even aged" and "monoculture" when applied to Douglas-fir forests conjur up specters of cornfield-like timber stands rich only in their potential for insect outbreaks and mechanized harvest. While these forests of the Pacific Northwest do naturally tend toward even-aged Douglas-fir dominated stands (Franklin and Dyrness 1973), a number of factors disrupt such development. Site factors, animal-caused mortality, and chance occurrences such as fire and wind throw are some primary disruptive sources. Herbicides or fertilizers may be used to retard or stimulate growth of target species affected by the vagaries of site factors. Forest managers attempt to manipulate populations of rodents, lagomorphs, ungulates, and even black bears (Ursus americanus) to reduce damage to timber. In general, attempts to thwart mammal-caused forest damage have been less than totally successful (Black 1969), and mammals will continue to damage trees and thus unintentionally provide diversity within the forest.

Insects pose a significant threat to forest

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[3] Eric Forsman, Bill Mannan, Richard Reynolds, Howard Wight, Fred Ziellemaker.

Table 1.--Use by 84 birds of Douglas-fir plant communities in Oregon west of the Cascade Range summit. Twenty species dependent on holes for nest sites are printed in italics. X = uses that seral stage, but not for nesting; XX = nests in that seral stage; XXX = nests primarily in that seral stage.

Bird species (N = 84)	Seral stage and age, years				
	Grass, forbs 1-7	Shrub, sapling 8-15	Second growth 16-40	Older 2nd growth 41-120	Mature 120+
Savannah sparrow	XXX	X	-	-	-
Vesper sparrow	XXX	X	-	-	-
White-crowned sparrow	XX	XX	-	-	-
Song sparrow	XX	XX	-	-	-
Nighthawk	XX	XX	X	X	X
Oregon junco	XX	XX	XX	XX	XX
Fox sparrow	X	XXX	-	-	-
Chipping sparrow	X	XXX	-	-	-
Rufous-sided towhee	X	XXX	-	-	-
American goldfinch	X	XXX	-	-	-
Black-headed grosbeak	-	XX	XX	XX	XX
Bewick's wren	X	XXX	-	-	-
Lazuli bunting	X	XXX	-	-	-
Wilson's warbler	-	XXX	XX	XX	XX
Yellow warbler	-	XXX	X	-	-
Nashville warbler	-	XX	XX	X	-
Orange-crowned warbler	-	XX	-	-	-
Warbling vireo	-	XX	XX	XX	XX
Solitary vireo	-	XX	XX	XX	-
MacGillivray's warbler	-	XX	XX	XX	XX
Yellow-rumped warbler	-	XX	XX	X	X
Black-throated gray warbler	-	XX	X	XX	XX
Hutton's vireo	-	XX	XX	XX	X
Swainson's thrush	X	XX	XX	X	X
Varied thrush	X	XX	XX	XX	XX
Robin	X	XX	XX	XX	X
Common bushtit	-	XXX	X	X	X
Scrub jay	X	XXX	-	-	-
Stellar's jay	X	XX	XX	XX	XX
Western wood pewee	-	XX	X	XX	XX
Western flycatcher	-	XX	XX	XX	XX
Traill's flycatcher	-	XX	X	-	-
Calliope hummingbird	X	XXX	-	-	-
Mourning dove	X	XX	XX	-	-
Mountain quail	X	XXX	X	X	X
Blue grouse	X	XX	-	XX	XX
Ruffed grouse	X	XX	XX	-	-
Sharp-shinned hawk	-	X	XX	XX	XX
Saw-whet owl	-	X	XX	XX	XX
Cooper's hawk	-	X	XX	XX	-
Pigeon hawk	-	X	XX	XX	-
Pygmy owl	-	X	X	XX	XX
Long-eared owl	X	X	XX	XX	-
Rufous hummingbird	X	X	XX	XX	XX
Tree swallow	X	XX	XX	X	X
Purple martin	X	XX	XX	X	X
Western bluebird	X	XX	X	-	-
Mountain bluebird	X	XX	X	-	-
Great horned owl	X	X	XX	XX	X
Crow	X	X	XX	XX	XX
Flicker	X	X	X	XX	XX
Gray jay	-	X	X	XX	XX

Table 1.--(continued)

Bird species (N = 84)	Seral stage and age, years				
	Grass, forbs 1-7	Shrub, sapling 8-15	Second growth 16-40	Older 2nd growth 41-120	Mature 120+
Yellow-bellied sapsucker	-	X	X	XX	XX
Black-capped chickadee	-	X	XX	XX	X
Winter wren	-	X	XX	XX	XX
Golden-crowned kinglet	-	X	XX	XX	XX
Ruby-crowned kinglet	-	X	XX	XX	XX
Red-tailed hawk	X	X	X	XX	XX
Bald eagle	-	-	-	XX	XX
Osprey	-	-	-	XX	XX
Band-tailed pigeon	X	X	-	XX	XX
Screech owl	-	X	X	XX	XX
Pileated woodpecker	-	X	X	XX	XX
N. three-toed woodpecker	-	-	X	XX	XX
Hairy woodpecker	-	X	X	XX	XX
Downy woodpecker	X	X	-	XX	XX
Olive-sided flycatcher	X	X	-	XX	XX
Chestnut-backed chickadee	-	X	X	XX	XX
Red-breasted nuthatch	-	-	X	XX	XX
White-breasted nuthatch	-	-	X	XX	XX
Brown creeper	-	-	X	XX	XX
Townsend's solitaire	X	XX	XX	XX	XX
Hermit thrush	-	X	X	XX	XX
Townsend's warbler	-	-	-	XX	XX
Hermit warbler	-	-	XX	XX	XX
Hammond's flycatcher	-	X	XX	XX	XX
Western tanager	-	X	XX	XX	XX
Evening grosbeak	-	X	X	XX	XX
Purple finch	-	X	X	XX	XX
Pine siskin	X	X	X	XX	XX
Red crossbill	-	-	-	XX	XX
Goshawk	-	-	-	X	XXX
Spotted owl	-	-	-	X	XXX
Vaux's swift	X	X	X	X	XXX
SUMMARY:					
Species occurring	38	73	61	65	60
% of total species occurring	45	87	73	77	71
Nesting primarily in that seral stage	2	12	0	0	3
Nesting species	6	40	34	54	49
% of total species nesting within seral stage	7	48	40	64	58
Species nesting in holes	0	4	4	14	15

yields. Management favoring even-aged, single-species stands essentially sets the table for the insects. We recognize the impact of widespread forest insect outbreaks not only in economic terms but also in terms of forest destruction. Yet, the implications to bird populations of widespread use of pesticides (such as occurred in the Northwest with the 1974 DDT-Douglas-fir tussock moth situation) are a persuasive argument for integrated control as a rational approach to pest problems (Odum 1971:445-447).

Again, the impact of management to achieve even-aged, single species stands leads to decreased diversity of the structure of the habitat--reducing the number of birds which can occupy such areas.

Elimination of Snags

Summarizing his research findings in Finnish forests, Haapanen (1965:194) stated that "Taken as a whole, silviculture clearly decreases the densities of bird species nesting in coniferous stands." He further points out that the lower density of hole-nesting birds is the most important factor involved in the decrease of total bird density in managed stands. We have identified some 20 species of hole-nesting birds in the Douglas-fir forests of western Oregon. The requirements of these hole-nesters were reviewed by Jackman (1974).

Forest managers have responded--preservation of snags for wildlife is rapidly becoming an accepted policy and is being implemented on many northwest forests. As in Finland, (Haapanen 1965), however, the practice of intensive timber management with shortened rotations will eliminate the potential for simple snag preservation to supply the required snags. The time for more creative snag management is here.

Elimination of Old-growth Forest

There is an element of the avifauna of the Douglas-fir forest that is dependent on mature forest stands (Table 1). These species have evolved to become specialists requiring the stability and diversity which only old-growth forests can provide. There are, in addition, a whole gamut of species which are dependent to a lesser extent on these old-growth stands. What particularly concerns us is the rate at which old-growth forests, and their attendant wildlife, are being eliminated. The only meaningful stands of old growth are already limited to public lands.

Over the past several years, Eric Forsman has been studying one of the old-growth obligates, the northern spotted owl (*Strix occidentalis caurina*). In the course of his work, Forsman located 123 habitats occupied by spotted owls; 64 of these either have been harvested or major harvest is planned. While some may wish to argue over the number of birds remaining, such species surely seem destined for endangered status unless timber management practices are altered.

MANAGEMENT IMPLICATIONS

How can we use our knowledge of the relationship between birds and habitat to manage birds while manipulating the habitat? We may be tempted to manage for diversity of non-game birds. As pointed out earlier, to manage on the basis of diversity alone would be far too impersonal from the birds' standpoint; we could lose valuable but rare species--or even assemblages of species--and these losses would not necessarily be reflected in the diversity measures. I believe the management goal should be to maintain the maximum number of species at densities most closely reflecting the natural situation. We should manage to maintain species composition and density--not to change it.

Thomas et al. (1973) presented a scheme to predict the impact of management treatments on birds based on the life form (nesting and feeding habitat requirements) of the species. Such an approach seems especially useful because it identifies the species assemblages of birds affected by various management practices and predicts the impact of the treatment. Clearly the manager should be concerned for those species negatively impacted by the management and take steps to ensure that they remain as a functional species in the management area.

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NONGAME BIRD COMMUNITIES IN NORTHWESTERN CONIFEROUS FORESTS[1]

John A. Wiens[2]

Abstract.--Northwestern coniferous forests contain relatively rich breeding avifaunas. Censuses record an average of 15.4 breeding species, and a total of 71 species are listed from 29 censuses. Only eight of these species occur with great regularity in the censuses, however, and most of these are widely distributed over North American coniferous forests. Total breeding densities and standing crop biomasses are relatively high in Northwestern forests. The avian community is dominated by foliage-feeding insectivores, although these forms contribute a smaller proportion of the avifauna than in other North American coniferous forests. Northwestern forest bird communities undergo considerable seasonal and yearly change in composition and species abundances.

If these forest habitats are to be managed for the well-being of nongame birds, we must (1) discard the notion that "diversity" per se is an appropriate goal; (2) reach a better understanding of the habitat requirements of the native species, and identify forms that may be good "indicators" of habitat deterioration; and (3) determine the proper areas of habitat blocks that enhance the success of the most important bird populations or species assemblages.

INTRODUCTION

Coniferous forests give the Western United States much of its vegetational texture. In the Pacific Northwest, especially, the range of composition and stature in coniferous forests is spectacular, and is the product of both the sharp gradients in environmental features (notably precipitation and temperature) and a wide range of scales and intensities of human disturbances. Such heterogeneity, coupled with the diverse goals accompanying human utilization of these forests, thwarts the application of simple and uniform management practices to the wildlife inhabitants as well as the vegetation. What are appropriate harvesting practices in Douglas-fir forests are not directly applicable to ponderosa parklands in more arid areas, and objectives developed with large-ranging mammals in mind may fail miserably when applied to small songbirds or raptors in the same area.

There is no ready solution to this enigma, but beginnings must be founded upon an appreciation for and knowledge of the natural biota of these forests, and of their habitat requirements and sensitivities to environmental changes. In this paper I will summarize in a very general fashion some of the chief biological attributes of non-game bird communities occupying coniferous forests in the Pacific Northwest. In the Tucson Symposium I reviewed coniferous forest avifaunas in a broader and more detailed manner (Wiens 1975), and this paper is essentially a condensation of that treatment. I have made no attempt to update my survey of the literature, or to include the several censuses recorded from these habitats since 1974. My objectives are primarily to provide a capsule summary of the composition and functional organization of Pacific Northwest coniferous forest bird faunas, suggest something about their overall stability, note some possible effects of habitat alterations, and emphasize a few points for consideration in the development of management policies.

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THE BREEDING AVIFAUNA

Drawing information from 29 censuses of breeding bird populations conducted by various observers in a spectrum of Northwestern coniferous forests (Wiens 1975), I have tabulated the occurrence of nongame bird species in this forest region, expressed as the proportion of the censuses in which each species appeared (Table 1). Seventy-one species are represented, but of these, 19 (27%) were recorded in just a single census. Eighteen (25%) occur in more than one-quarter of the censuses, 8 (11%) in over half. In terms of frequency of appearance in censuses, these latter species may perhaps be considered most "typical" of Pacific Northwest coniferous forests. They are the hairy woodpecker, Western flycatcher, Steller's jay, chestnut-backed chickadee, red breasted nuthatch, winter wren, golden-crowned kinglet, and junco. Of these species, all but the hairy woodpecker, Steller's jay, and winter wren are frequently also fairly abundant where they are present in this region. Further, all but the chestnut-backed chickadee and Western flycatcher, and to a lesser degree the Steller's jay, occur in a wide distribution over most of the coniferous forest regions of North America. So the most widespread and generally most abundant species in the coniferous forests of the Northwest are generally those which are broadly characteristic of North American coniferous forests.

Table 1.--Frequencies (percent of 29 censuses in which recorded) of breeding bird species in Pacific Northwest coniferous forests. See Wiens (1975) for details of censuses

Species	Frequency (%)
Band-tailed Pigeon (*Columba fasciata*)	3
Mourning Dove (*Zenaidura macroura*)	10
Rufous Hummingbird (*Selasphorus rufus*)	10
Allen's Hummingbird (*Selasphorus sasin*)	21
Common Flicker (*Colaptes auratus*)	24
Pileated Woodpecker (*Dryocopus pileatus*)	14
Acorn Woodpecker (*Melanerpes formicivorus*)	10
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	17
Hairy Woodpecker (*Dendrocopus villosus*)	66
Downy Woodpecker (*Dendrocopus pubescens*)	17
Black-backed Three-toed Woodpecker (*Picoides arcticus*)	3
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	3
Hammond's Flycatcher (*Empidonax hammondii*)	14
Dusty Flycatcher (*Empidonax oberholseri*)	7
Western Flycatcher (*Empidonax difficilis*)	76
Western Wood Pewee (*Contopus sordidulus*)	28
Olive-sided Flycatcher (*Nuttallornis borealis*)	28
Violet-green Swallow (*Tachycineta thalassina*)	7
Tree Swallow (*Iridoprocne bicolor*)	3
Steller's Jay (*Cyanocitta stelleri*)	76
Gray Jay (*Perisoreus canadensis*)	14
Black-capped Chickadee (*Parus atricapillus*)	7
Chestnut-backed Chickadee (*Parus rufescens*)	90
Common Bushtit (*Psaltriparus minimus*)	21
Wrentit (*Chamaea fasciata*)	24
Red-breasted Nuthatch (*Sitta canadensis*)	72

Species	Frequency (%)
Pygmy Nuthatch (*Sitta pygmaea*)	24
Brown Creeper (*Certhia familiaris*)	12
House Wren (*Troglodytes aedon*)	7
Winter Wren (*Troglodytes troglodytes*)	69
Bewick's Wren (*Thryomanes bewickii*)	17
American Robin (*Turdus migratorius*)	38
Varied Thrush (*Ixoreus naevius*)	17
Townsend's Solitaire (*Myadestes townsendi*)	3
Hermit Thrush (*Hylocichla guttata*)	38
Swainson's Thrush (*Hylocichla minima*)	31
Western Bluebird (*Sialia mexicana*)	3
Golden-crowned Kinglet (*Regulus satrapa*)	66
Ruby Crowned Kinglet (*Regulus calendula*)	7
Starling (*Sturnus vulgaris*)	3
Hutton's Vireo (*Vireo huttoni*)	24
Warbling Vireo (*Vireo gilvus*)	10
Tennessee Warbler (*Vermivora peregrina*)	7
Orange-crowned Warbler (*Vermivora celata*)	24
Yellow Warbler (*Dendroica petechia*)	3
Magnolia Warbler (*Dendroica magnolia*)	3

Species	Frequency (%)
Yellow-rumped Warbler (*Dendroica coronata*)	3
Townsend's Warbler (*Dendroica townsendi*)	7
Hermit Warbler (*Dendroica occidentalis*)	34
Bay-breasted Warbler (*Dendroica castanea*)	3
Blackpoll Warbler (*Dendroica striata*)	3
Northern Walterthrush (*Seiurus noveboracensis*)	3
MacGillivray's Warbler (*Oporonis tolmiei*)	14
Wilson's Warbler (*Wilsonia pusilla*)	45
American Redstart (*Setophaga ruticilla*)	3
Western Tanager (*Piranga ludoviciana*)	38
Black-headed Grosbeak (*Pheucticus melanocephalus*)	14
Evening Grosbeak (*Hesperiphona vespertina*)	10
Purple Finch (*Carpodacus purpureus*)	21
House Finch (*Carpodacus mexicanus*)	3
Pine Grosbeak (*Pinicola enucleator*)	3
Pine Siskin (*Spinus pinus*)	38
American Goldfinch (*Spinus tristis*)	14
White-winged Crossbill (*Loxia leucoptera*)	3
Rufous-sided Towhee (*Pipilo erythropthalmus*)	34
Junco (*Junco hyemalis*)	97

Species	Frequency (%)
Chipping Sparrow (*Spizella passerina*)	14
White-crowned Sparrow (*Zonotrichia leucophrys*)	14
Fox Sparrow (*Passerella iliaca*)	3
Lincoln's Sparrow (*Melospiza lincolnii*)	3
Song Sparrow (*Melospiza melodia*)	24

This observation raises the question of how distinctive breeding avifaunas of the Northwestern forests are, and how closely the entire species assemblage of these forests resembles those found in other coniferous forest regions of North America. In the earlier analysis I divided these forest regions into seven categories, including six geographic areas and a distinction between immature and mature successional stages of coniferous forests in the Northeast (Wiens 1975). Similarity index values were calculated between the species list for Pacific Northwest forests and those of the other categories, using the equation

$$S = \frac{2C}{A + B}$$

where C = species common to both compared areas, A = total number of species recorded in Northwestern forests, and B = total number of species recorded in compared forest type. These index values (Table 1) indicate about a 50% overlap in species lists of Northwestern forests with those of most other areas, with lower similarity to the more distant Southeastern forests, and greater similarity to the more proximate Rocky Mountain coniferous forests. These similarity values are strongly influenced by the less common species in each region, and were the analysis to be confined to the most abundant species in each region, the index values would suggest greater overall similarity. We may conclude that while the coniferous forests of the Northwest do contain some distinctive species, their breeding avifaunas are in general not highly unique in comparison to coniferous forest avifaunas elsewhere in North America.

Table 1.--Similarity index values for comparisons of Northwestern coniferous forest breeding avifaunas with those of other North American coniferous forest types (see Wiens 1975).

Northeast (immature stages)	0.48
Northeast (mature stages)	0.44
Southeast	0.31
Northern (boreal)	0.54
Rocky Mountain	0.68
Sierra Nevada	0.57

This conclusion does not emerge as clearly when the bird communities of Northwestern coniferous forests are considered in terms of some of their structural or functional attributes instead of their species composition. The average number of species encountered in censuses is lower than that in coniferous forests of Northeastern and Southeastern regions and in the Sierra Nevadas, and generally similar to that of Boreal and Rocky Mountain forests (Table 3). By way of comparison, these values are roughly 2-4 times greater than species numbers recorded in comparable breeding censuses in North American rangeland or shrubsteppe habitats. Despite the intermediate number of breeding species present in coniferous forests of the Northwest, the number of breeding individuals per unit area is considerable, and averages more than that of any other coniferous forest region in North America (Table 3). Total standing crop biomass of breeding birds (g wet weight/ha) is also comparatively high in the Northwestern forests, but so is that in coniferous forests in the Southeast, Northeast, and Sierra Nevadas. Given the greater number of individuals present in the Northwestern forests, this suggests that the avifauna on the average is composed of somewhat smaller species than those characterizing the other forest regions. This difference is especially apparent in a comparison of

Table 3.--Features of breeding bird community structure in coniferous forests of different regions of North America. Values are means, with standard deviations in parentheses. From Wiens (1975)

Region	Censuses	Number of Species	Density (individual/km^2)	Standing Crop Biomass (g/ha)
Northwest	17	15.4(6.1)	1456(621)	283(102)
Sierra Nevada	6	21.3(5.0)	796(410)	251(215)
Rocky Mountain	17	14.0(5.0)	736(575)	188(147)
Northern (Boreal)	4	14.5(3.9)	466(216)	80(32)
Southeast	10	21.6(5.5)	1221(407)	281(95)
Northeast (mature)	18	22.6(4.2)	1341(343)	273(146)
Northeast (immature)	9	11.1(3.7)	329(150)	65(50)

Northwestern with Sierra Nevada forest avifaunas: total density averages almost twice as much in the Northwestern forests, but biomass is only slightly greater -- the Sierra birds are obviously larger, on the average. One feels that such patterns hold promise of some "adaptiveness" in the structuring of the avian community, but the meaning of the patterns is as yet elusive.

These analyses of density and biomass are based upon species as the chief categories, but documentations based upon ecological and behavioral categories may be equally meaningful. Following Salt (1957), Bock and Lynch (1970), and Anderson (1970,1972), we may group species according to the substrate type in which foraging occurs (foliage, timber, ground, and air) and the major component of the diet during the breeding season (invertebrates or seeds). The timber-feeding category (most of which are largely insectivorous) is further divided into forms that practice searching tactics and those that drill timber to obtain food. After each species recorded in a census has been categorized in this manner, density and biomass values may be totaled for each category to provide information of the structuring of the avifaunas according to these ecologically-defined units. The results of these analyses are summarized for the various coniferous forest regions in figure 1.

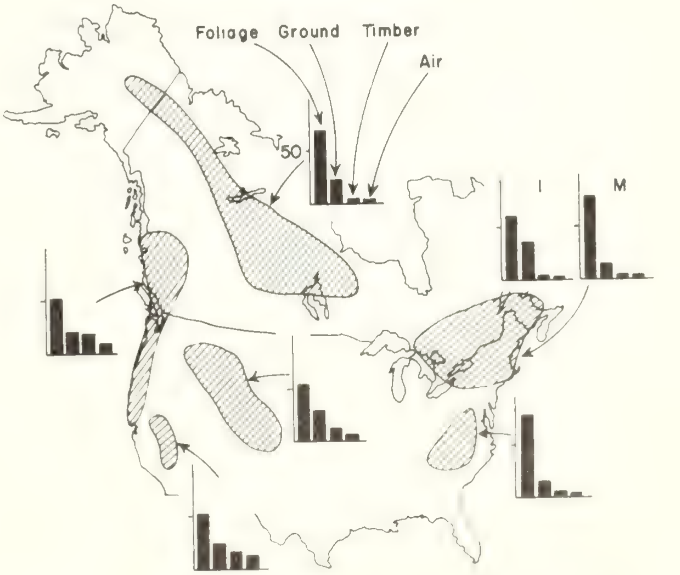

Figure 1.-- Relative densities (percentages of total density) of major ecological "guilds" of breeding birds in coniferous forest regions of North America. Values are means of the censuses for each area. For the Northwest region, I = Immature forest stages, M = Mature forest stages.

It is apparent that the foliage-feeding forms numerically dominate the avifauna in all North American coniferous forests, with ground-feeding, timber-foraging and aerial feeders less important in decreasing order. The proportional dominance of foliage feeders is greatest in northeastern mature and southeastern coniferous forests. All ground-foragers attain their greatest "importance" in early successional stages of northeastern forests, and timber and air-feeding forms appear to be numerically most abundant in western coniferous forests. When the foliage-feeding "guild" (Root 1967) is divided according to diet habits, we see that insectivorous forms contribute the greatest share of the foliage-feeding element in all forest types, while the percent of all individuals foraging for seeds or fruits in canopy foliage is relatively uniform in all forests except those of southeastern United States. Seed-eaters predominate in the ground-foraging component, especially in immature northeastern forests. Among the timber-foraging group, "searchers" appear to be more prevelant in western montane and northwestern coniferous forests than in the remainder of North America, and drilling forms show a similar tendency to increase in relative density as one moves West. These patterns are summarized in more detail for the Northwestern forests in Figure 2. On the average, foliage feeding forms comprise more than half of the individuals present, with the remaining individuals more or less evenly distributed among the other guilds. In terms of density, insectivorous forms predominate among the foliage-feeding forms; but when biomass is considered, the seed-feeding forms gain greater representation.

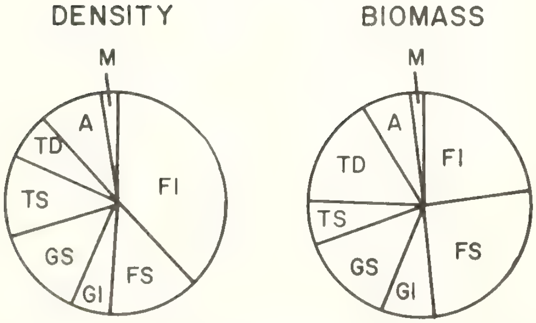

Figure 2.--Proportions of various functional categories or "guilds" of breeding birds in northwestern coniferous forests, as recorded in censuses. FI = foliage-feeding insectivore, FS = foliage seed-feeding, GI = ground-feeding insectivore, GS = ground feeding granivore, TS = timber searching, TD = timber drilling, A = air-feeding, M = miscellaneous.

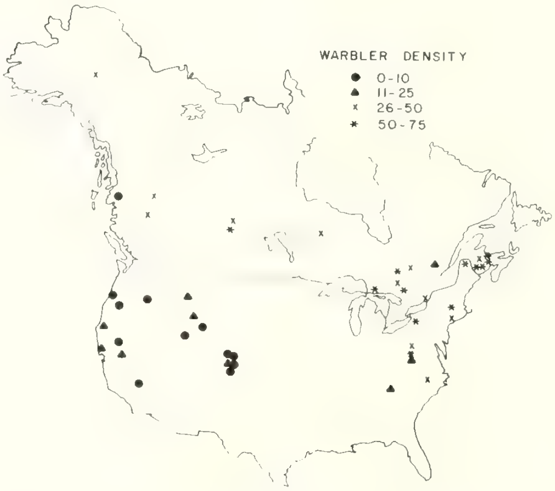

Figure 3.--Relative densities (percentages of total number of individuals of all species) of warblers (Parulidae) recorded in North American breeding censuses.

These patterns prompt a closer examination of the foliage-feeding guild. Various warbler species are important constituents of coniferous forests in many areas of North America, and all are foliage-feeding insectivores. In Figure 3 I have plotted several categories of relative densities (i.e., the percentage of all individuals recorded in breeding censuses) of all warbler species combined. It is apparent that warblers constitute the major component of breeding avifaunas throughout northeastern and southeastern United States (especially in mature coniferous forests) while their relative densities are lower in northern boreal forests and lower still in the coniferous forests of the Rocky Mountains, Sierra Nevadas and the Northwest. Thus both the number of warbler species and their relative and absolute densities are substantially lower in western forests than in eastern North America, and the relative paucity of warblers in the West is not compensated for by a proportionate increase in other foliage-feeding insectivores. The relatively low number of warbler species in the West may stem from biogeographic events and speciation processes (Mengel 1964, 1970), but the differences in total densities and biomass of foliage insectivores, especially warblers, immediately suggest that there may be differences in prey resource availability in the different forest regions. The avian data suggest that endemic levels of foliage-feeding insects during the breeding season may be lower in western than eastern coniferous forests and/or that population outbreaks or epidemics of defoliating insects may be less frequent and reach less spectacular levels in western than eastern North America. These regional differences are intriguing, not only for their theoretical significance but for their importance in the formulation of habitat management strategies, and bear closer examination in light of studies of forest entomologists.

Avifaunal Stability

The patterns of avian community structure just summarized are in a sense static representations, for they do not consider temporal variation in population densities or species compositions. Knowledge of the magnitude of temporal change in avifaunal structure is crucial to the formulation of sound management strategies. Thus management ploys which attempt to produce stability in inherently fluctuating populations and communities may be inappropriate. On the other hand, evidence of apparent instability in population and community structure may lead us to suspect that management is required, but before implementing such measures, it is necessary to determine whether the fluctuations are natural or result from human alterations of the natural systems. Unfortunately, not a great deal of information is available on the inherent stability of bird populations in coniferous forest habitats. There are, of course, several time scales to change or stability of avifaunal structure. Here I consider some selected examples of the patterns of seasonal change, year-to-year fluctuations, and changes during ecological succession.

Anderson's (1970) studies in the coniferous forest of western Oregon provide an example of the sorts of seasonal changes which may characterize Northwestern coniferous forests. Anderson conducted population censuses in several plots along a successional-elevational gradient at six times during the year (Figure 4). While there were differences in the patterns exhibited in the different forest types, the general patterns of change are similar in all stands. Total avian density decreased slightly from winter into early spring and then more than doubled by the late spring censuses. Peak densities were recorded in all stands at this time, no doubt because of the inclusion of a great many migrant individuals in the censuses. Densities decreased from this late spring peak to the breeding density levels characteristic of early summer, which were higher in all stands than the wintering densities. There was a gradual decline in density from these breeding levels to the wintering levels. Trends in total standing crop biomass were similar, although the magnitude of fluctuation was greater. Total biomass was greatest during the late spring migratory period, but in at least some stands wintering biomass was nearly as great as that recorded during the breeding season.

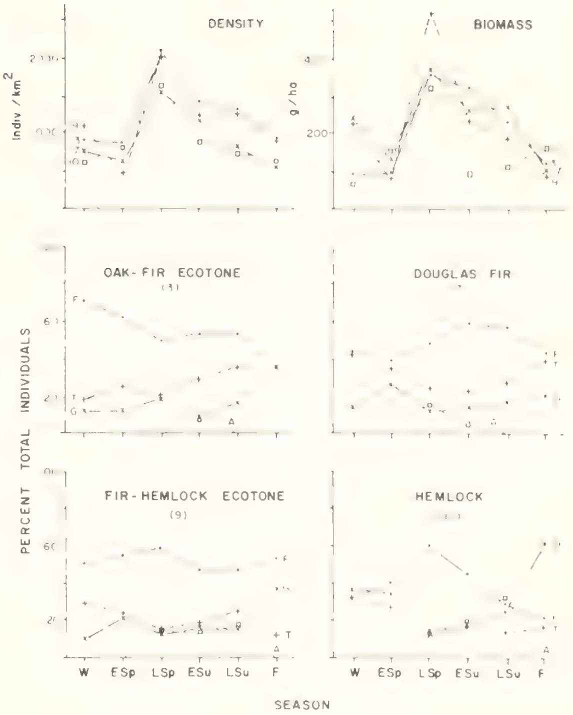

Figure 4.--Seasonal changes in avian density and biomass and in the ecological composition of four stages of coniferous forest succession in western Oregon: 3 = oak-fir ecotone, 7 = douglas fir, 9 = fir-hemlock ecotone, 10 = hemlock "climax". Seasons: W = winter (2 November - 1 March), ESp = early spring (2 March - 15 April), LSp = late spring (16 April - 1 June), ESu = early summer (2 June - 15 July), LSu = late summer (16 July - 1 September). F = fall (2 September - 1 November). Ecological categories: F = foliage-feeding, G = ground-foraging, T - timber-foraging, A = air-feeding. From Anderson (1970).

Anderson's data also permit evaluation of seasonal changes in the ecological structuring of these forest bird communities (Figure 4). Here differences between stands are greater, but some general trends can nonetheless be distinguised. The occurrence of air-feeding species in the avifauna tended to be restricted to the spring and summer periods in all stands, while ground-feeding forms tended to account for a greater portion of the avifauna in fall than at other times of the year. Foliage- and timber-foraging species assemblages exhibited rather different patterns in the different stands but both underwent seasonal changes in "importance" in most situations.

Table 4.--Mean coefficients of variation[1/] of breeding density and biomass values recorded in censuses conducted over several successive years in coniferous forest stands. From Wiens (1975).

Region	N	Density	Biomass
Northwest	4	11.4	17.2
Sierra Nevada	5	17.2	17.9
Rocky Mountains	4	16.7	31.8
Northern (Boreal)	2	2.2	12.5
Southeast	1	37.2	39.3
Northeast (mature)	3	2.3	5.7
Northeast (immature)	2	26.2	30.1

[1/] Coefficient of variation = $\frac{100s}{\bar{x}}$, where entries are yearly values.

To analyze annual variation I calculated the coefficient of variation (CV) of density and biomass values for each census location in which more than one annual breeding census was available. These coefficients of variation were then averaged for each of the major coniferous forest regions of North America (Table 4). It appears from this admittedly superficial analysis that total avian densities in northern and northeastern mature forests are extremely stable from year to year, while total densities in immature successional forests in the northeast and in southeastern coniferous forests are notably variable. Annual variability is intermediate in the western forest types. Standing crop biomass variations exhibit the same relative trends, although biomass appears consistently more variable from year to year than density, reflecting shifts in the relative abundances of different-sized species.

It is uncertain to what degree these annual variations represent sampling error or true variation in actual densities. Still, the analysis suggests that apart from the apparently stable forests of northern and northeastern North America coniferous forests, avifaunas undergo substantial variations in density and biomass from year to year. In general, these coefficients of variation agree rather closely with those characterizing breeding avifaunas in various rangeland habitat types (Wiens and Dyer 1975). Thus the relatively diverse avifaunas of most coniferous forests appear to be no more stable on an annual basis than the low-diversity assemblages characterizing open rangeland habitats.

This analysis considers the annual stability of coniferous forest avifaunas in terms only of total density and biomass, and other measures of change are available. Järvinen and Väisänen (1976), for example, calculated the species diversity of several Fennoscandian woodlands over several years, and concluded that diversity in the communities exhibited only slight year-to-year change. This apparent stability in diversity, however, may mask considerable changes in total abundance and species composition, and these are critical to the real nature of forest bird communities and their management. Ideally, we should determine the relative stabilities of abundances of single species populations over several years, especially for the more abundant or "typical" coniferous forest forms.

Coniferous forest avifaunas also undergo change over a longer time interval, as the vegetation changes during ecological succession following disturbances toward the climax condition. Early stages generally support fewer species and individuals and less biomass than mature stages, and the species tend on the average to be larger and ecologically more dominant. The studies of Anderson (1970, 1972) permit closer definition of the changes during succession, at least in the oak-Douglas fir-hemlock sequence typical in western Oregon. Here total breeding densities were highest in oak-fir and fir-hemlock ecotonal stands, and lower in "pure" fir or hemlock stands, with the lowest densities recorded in the "climax" hemlock stand (Figure 4). Distributions of breeding biomass and species diversity followed similar trends. These results demonstrate the difficulty of making clear assessments of succession-defined changes, for succession inevitably involves transitional stages, and vegetational diversity (in flora and structure)is frequently greater in such transitions, influencing bird populations accordingly. Further, in many areas of Western North America, successional sequences are often associated with elevational gradients, so that several interacting sets of factors may contribute to the determination of avian community structure. Thus the censuses from western Oregon summarized by Wiens and Nussbaum (1975) followed not only a successional series, but were arrayed along moisture and temperature gradients as well. In that series of stands, as in Anderson's, greatest avian density and biomass were recorded in transitional stands.

Thus it appears that bird populations, responding in their selection of breeding habitat to features of vegetation structure, may change with major structural changes during forest succession (as from deciduous to coniferous stands). During transitions, when elements of both habitat types are intermixed, species characteristic of both types may be present, leading to an increase in species numbers, density, and biomass. In many local areas, however, successional seres are often assorted in patchy mosaics, reflecting the intermittant natures of past disturbances, so that clear patterns in avian distributions and responses are blurred. Still, some management implications seem clear: if high avian community diversity, density, and biomass are desired, forests should probably be managed to maintain transitional stages or mixtures. Clearcutting and even-age management probably do not contribute to such ends, especially when practiced over large areas or in large treatment blocks. While it is tempting (and commonplace) to suggest that these "high diversity" avian communities may also be most stable, and therefore play the most predictable roles in coniferous ecosystems (see below), such conclusions are without factual or theoretical support, and may be dangerously misleading.

EFFECTS OF HABITAT ALTERATIONS

Bird populations respond to the overall physical structure or physiognomy of habitats in their selection of breeding locations (Wiens 1969, Balda 1975, Sturman 1968, Ulfstrand 1976), and because of this close association with vegetation structure, bird populations (especially those of resident species) may be excellent "indicators" of the impacts of various alterations, both man-made and natural, in the total forest ecosystem (Adams and Barrett 1976). Coniferous forests are subjected to a variety of alterations, most of them resulting from man's intentional or unintentional activities. Some, such as clearcutting, effectively remove the forest, and understandably produce major changes in avian populations and communities. Other alterations are less massive, however, and have more subtle effects. Chief among such manipulations are clearing of underbrush and controlled or uncontrolled burning.

Several selected studies may be used to demonstrate some effects of such alterations. Hagar (1960), for example, analyzed the changes in avian communities during reforestation following clearcutting of Douglas-fir forest in northern California. Logging of course altered forest structure, and thus bird species composition, and produced an initial decrease in total density. Within a year, however, breeding densities equaled pre-cutting densities, and 3 years following cutting, densities exceeded those recorded in mature forests in the area. Avifaunal differences between pre-cut forests and brush stages of cutover regeneration were least in the breeding season, while fall and winter densities in logged areas were 2-3 times those in forests. Logging especially favored granivorous species, such as juncos and mountain quail, a shift in ecological composition which may be important in reforestation processes. Meslow and Wight (1975) also analyzed the avifaunal changes accompanying forest succession following harvesting in western Oregon Douglas-fir forests, and noted the effects of several management practices. Especially critical (and controversial) is the retention of dead snags in forests subjected to harvesting. Forest managers frequently regard snags as safety and fire hazards, and recommend their removal. Snags constitute an important (and probably limiting) resource for both hole-nesting and aerial-feeding birds, however, and their removal may seriously impair habitat suitability to such species. Meslow and Wight (1975) touched on the importance of snags to some of the bird species typical of western Oregon forests. McClelland and Frissell (1975) examined in more detail the importance of snags to bird populations in western Montana larch and Douglas-fir forests, and offered some preliminary management recommendations for recognizing suitable snags.

Uncontrolled burning (i.e., forest fires) may promote avifaunal changes parallel to those following logging. Bock and Lynch (1970) compared burned and unburned Jeffrey pine-white fir stands in the Sierra Nevadas 6-8 years after an intense fire. Breeding avifaunas on the burned areas were slightly richer in species and more diverse than in unburned plots. Breeding densities were similar in both types, but standing crop biomass was greater on the burned area. Foliage-searching birds predominated in the unburned forest, while brush-ground feeding forms were most abundant in burned areas. It seems likely that a shift toward increased granivory also followed burning.

Less intensive cutting or burning predictably has less profound effects on breeding bird communities. In sequoia forests, Kilgore (1971) reported that clearing and prescribed burning of understory brush and saplings producted changes in the species composition of the avifauna, but not in total standing crop biomass. Clearing primarily affected birds which nested or fed in the ground and brush layers, but overall this was the least important layer in these forests.

Such habitat alterations undeniably influence the bird populations and communities. But as Thomas et al. (1975) have observed,

"...this is neither good nor bad--it merely is. The avifauna changes to include those species best adapted to, and most favored by, a new habitat complex. The thing to recognize is that burning, controlled or wild, will probably add diversity to a forest and cause changes in the avifauna that reflect habitat alterations."

MANAGEMENT CONSIDERATIONS

Bird populations and communities are tied into the functional framework of coniferous forests in a myriad of ways. They consume energy and nutrients; but within this context they may exert governing influences on patterns of insect and seed abundance, cycling, dispersion, reproductive potential, and dispersal. Such avian roles in coniferous forests have been reviewed by Wiens (1975), and Pank (1974), and will not be elaborated here. Nonetheless, some important questions remain. Does consumption of a moderate portion of conifer seedfall inhibit forest regeneration following disturbance? Do birds play a role in seed dispersal and thus enhance natural successional processes? Does the localized thinning of seedlings by birds reduce subsequent competition among saplings and promote growth? How are the patterns of seed consumption by coniferous forest birds related to those of small mammals? What are the real effects of insectivorous birds in extending the time frame of endemic-epidemic oscillations in pest insect populations? What are the roles of alternate food supplies in avian responses to fluctuations the populations of insects or seeds of economic importance? Unfortunately, our approach to exploring such questions has generally been more inferential than empirical. To assign economic parameters to the management of nongame birds will require assessment of the true relationships of avian consumption patterns to prey population structure, spatial dispersion, and dynamics.

Intelligent management of coniferous forests in an economic fashion with regard to optimizing the biological settings for nongame bird species is so fraught with "maybe," "it all depends," "yes but," and "perhaps if we try this" clauses that it may all seem hopeless. I can't really dispell that feeling, but I do wish to offer some general comments bearing on three elements of management of nongame bird populations.

1) It is a maxim in some management quarters that diversity is of itself good, and that enhancement of diversity is a valid management objective. To some degree this stems from the speculations bandied about in Ecology over the past decade that equated high diversity with stability; most managers prefer to deal with a stable (and thus predictable) system, so diversity is good. But the relation between diversity and stability has eroded upon close examination (if in fact it ever was real). Further, the emphasis upon diversity stemmed from the fashion in studies of avian community studies to calculate bird species diversity and derive associations with some measure of foliage volume distribution or vegetation structure. But these relationships turned out to be only very general (Balda 1975, Willson 1974), and obscured much valuable information about underlying cause-effect relationships. "Diversity," after all, is a measure that is insenstive to which species are present in an area, how they functionally relate to one another and to the forest ecosystem, whether they are native elements of the community or invaders. Doubtlessly we could increase the diversity of forest avifaunas by shaping the habitat to mimic some urban parkland (say, a cemetery), but at the expense of the natural community. The concept of diversity per se really has no place in resource management.

2) If management objectives are attuned to include consideration of nongame birds, should these be directed to single species populations or to assemblages or suites of species? Should attention be focused upon native species, upon "economically important" species (such as insectivores --- woodpeckers, warblers, flycatchers), upon only rare or endangered forms (as officially designated), or upon some other complement of spcies? Unfortunately, no single answer suffices. I feel management should be directed to maintenance of habitat conditions suitable for the continued success of suites of species that are characteristic of coniferous forests in the Northwest (Table 1). The avifaunas which occur naturally in these forests are not random assemblages, but represent series of species which occur together because of common adaptations to one another, to their food and habitat resources, and to the environment they experience. Habitat alterations that cause the disappearance of some of these species and facilitate the invasion of others change the avian community. At some point these changes become extensive enough that the community is no longer "natural", and to the extent that the natural communities represent sets of more of less harmoniously adjusted species, this may destabilize community relationships and disrupt any functional roles the bird populations may play in ecosystem dynamics.

Unfortunately, we have no idea at which point this occurs, if it ever does. With a better understanding of the habitat relationships of coniferous forest birds and some means of sensing when disruption of native avifaunas seems imminent, however, sound management may be initiated. Multivariate approaches to habitat analysis (e.g., Anderson and Shugart 1974, Shugart et al. 1975, Conner and Adkisson 1976) may provide a valuable tool in defining the habitat relations of species and the linkages among suites of coniferous forest birds. And Verner (1975) has suggested that management could be simplified if a small set of species populations could be monitored as indicators of the suitability of habitat conditions for the avian community as a whole. These species should be those most sensitive to habitat disruptions, and Verner has proposed that larger carnivores such as hawks, owls, or some of the larger insectivores may be the first species to react negatively to habitat deterioration, by virtue of their larger territories and position at the terminus of food webs. Resident species may also be more sensitive than seasonal migrants, since they lack the "escape" from habitat decay afforded by migration.

3) Management must also consider the spatial requirements of nongame bird populations. We must determine the sizes of blocks of unbroken forest habitat which are essential to harbor essentially "stable" bird populations. Here the spatial requirements of wide-ranging forms, such as jays, some woodpeckers, and especially forest raptors, may set the limits. What size of forest block is required, for example, to insure continuing reproductive success and survival of a pair of pileated or three-toed woodpeckers, or a pair of goshawks? Is our management policy to aim at maintenance of one pair, or two, or ten? What sizes of habitat blocks, defined by the requirements of the wide-ranging species, will also insure success of small foliage insectivore populations, or ground-foragers? These questions are critical, but as yet unanswered.

If blocks of suitable habitat are set aside as nongamebird management areas, they essentially become "islands" in a sea of habitats modified by man. Island biogeography theory has developed relationships between island areas, isolation, and age to species abundance and richness, and recently this theory has been introduced into considerations of refuge or management area planning (Wilson and Willis 1975). There are general relations between the size of an area and the number of bird species it supports, so if the aim of management is to maintain or enahance species diversity, the larger the nature reserve the better (Moore and Hooper 1975). Such uninhibited application of a theory which is still in a very general developmental stage is overly simplistic, however (Simberloff and Abele 1976). Different species respond to increasing area of habitat blocks in different ways, and sound management should be founded upon a knowledge of the area response patterns of the most important species or suite of species (as documented neatly for British woodlands by Moore and Hooper 1975).

At another level, the pattern of interspersion of habitats within a forested area may be critical. Maintenance of representatives of various successional seres within an area is increasingly recognized as a management objective, but do we know how such areas should be arrayed with respect to one another? Is it best to maintain an old-growth stand adjacent to a clear-cut, or to a shrub stage, or to an even-age or multi-age stand? What sort of internal heterogeneity should managed stands possess? Surely even-age monocultures with even spacing of trees, no spaces in the canopy, and no snags must represent structurally sterile habitat, and the inclusion of snags, or air-spaces within the canopy, or patches of non-managed tree species in a stand may render a forest block much more attractive to a broader variety of characteristic coniferous forest species. I consider definition of these spatial influences on bird populations to be our most pressing research priority.

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NONGAME BIRD COMMUNITIES IN NORTHWESTERN RANGELANDS[1]

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Abstract.--Pacific Northwest rangelands contain small assemblages of nongame birds. Our survey records 27 species breeding in shrubsteppe habitats of this region, although only 3-6 of these species are usually recorded in any local area. A cluster analysis of observations derived from roadside censuses indicates that the avian community of this shrubsteppe is distinctly different from that of nearby ponderosa parkland/high desert plateau habitat and from the deciduous/coniferous forests of the mountains and coastal areas. Further, the shrubsteppe is not avifaunally homogeneous itself, containing somewhat different species complexes in different areas. Management decisions made for one local area of this rangeland may thus be inappropriate for another area.

The dominant breeding species of the Northwest shrubsteppe are the horned lark, loggerhead shrike, marsh hawk, sage thrasher, Brewer's sparrow, and sage sparrow, with the grasshopper sparrow, lark sparrow, sage grouse, golden eagle, ferruginous hawk, prairie falcon, and black-throated sparrow less abundant but still characteristic. Management should emphasize these species, for they are the most reliable "indicators" of natural shrubsteppe bird communities.

Studies in southeastern Washington reveal that the major breeding species are highly insectivorous in diet during spring, while winter diets of the single wintering species (horned lark) are composed largely of grass and forb seeds. Recent conclusions that local bird populations, by preferentially consuming seeds used in rangeland reseeding programs, may intensify rangeland degradation, seem totally unwarranted.

Habitat alterations in shrubsteppe rangelands affect nongame bird populations primarily through changes in shrub coverage. These changes may or may not produce changes in the total abundance of nongame birds, but they undoubtedly alter the abundances of several of the characteristic species, and may lead to the elimination of those forms most closely associated with shrub cover.

INTRODUCTION

Much of western North America is characterized by a rigorous physical environment -- precipitation is generally low and temperature ranges on a daily or annual basis are frequently extreme. These general climatic patterns, with thermal and water stresses that are variable in time and often severe, impose constraints on vegetational development. The vegetation is thus relatively simple, both floristically and physiognomically, and production rates are relatively low. The primary utilization of these arid and semiarid regions is for grazing, although in some areas cereal grain agriculture is successful.

In the Pacific Northwest, the rain shadow created by the Cascades (and, to the south, the Sierra Nevadas) has produced a vast interior rangeland dominated by vestiges of bunchgrass prairie, and by large expanses of shrubsteppe or shrub desert (Daubenmire 1970, Franklin and Dyrness 1973). This rangeland is often considered to be of inferior quality for grazing of domestic stock (a view challenged by McKell 1975), and in at least some areas large-scale shrub control efforts and/or reseeding programs are practiced under the guise of "range improvement" (Vale 1974). These rangeland habitats, by virtue of their vegetational simplicity and environmental stresses, support relatively small assemblages of nongame birds (Wiens 1974, Cody 1974, Wiens and Dyer 1975, Rotenberry MS), and alterations in the habitat may thus have profound influences on avian populations. Our objectives here are to describe the composition of Northwestern rangeland avifaunas, chiefly during the breeding season, to examine the "stability" of these communities under natural conditions, and to consider some effects of habitat alterations on nongame bird populations. We draw primarily from results of our own studies in Washington and Oregon, conducted largely in Artemisia - dominated shrubsteppe.

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AVIAN POPULATIONS

Spring

Birds generally found in the Pacific Northwest shrubsteppe are listed in Table 1. Twenty-seven species (permanent and summer residents) regularly breed in this habitat, but generally only three species occur in numbers sufficiently large to be consistently included in standard areal censuses (usually 10 - 40 ha, depending on the study). Several more species may be recorded intermittently such that the average number of species per plot in sagebrush and/or bunchgrass rises to six (estimated from Wing 1947, 1949; Johnsgard and Rickard 1957; Feist 1968; Rotenberry MS).

This ranges from a third to a fifth that reported for various forest bird censuses (for example, Wallace 1970, Karr 1968). As will be shown below, this trend continues even when census areas are enlarged to over 25 km^2.

This low species number limits the complexity of bird communities, and is quite likely a result of several factors. Most certainly the extremities of climate impose checks on birds. Hot, dry summers require physiological and/or behavioral mechanisms for thermoregulation and maintenance of water balance. Sage sparrows (Moldenhauer and Wiens 1970) and horned larks (Trost 1972) seem to have solved these problems behaviorally, although Trost reports that the thermoregulatory ability of desert horned larks (Eremophila alpestris ammophila) is superior to that of larks from a more mesic environment (E. a. actica), and he suggests that this is probably a physiological correlate of behavior differences. The very cold winters and occasional persistent snow cover require a different set of thermoregulatory abilities, and restrict the amount of food available to permanent and winter resident species. The simplicity of the vegetation structure, especially when compared with that of a forest (Karr 1968) or even a scrub desert (Tomoff 1974), contributes to a reduction in bird species numbers and diversities.

Is the avifauna of the Pacific Northwest shrubsteppe really different from that of surrounding habitat types? If so, are there different bird communities within the shrubsteppe? What species may be considered diagnostic of this association? To help answer these and other questions in a quantitative and objective manner, the roadside counts of the North American Cooperative Breeding Bird Survey (Robbins and Van Velzen 1967) will be employed.

A roadside count is basically a 25-mile (40 km) transect with sampling points every half mile (0.8 km). The observer drives along a predetermined route, stops for 3 min. at each point, and records the species and numbers of all birds seen and heard within a quarter mile (0.4 km) radius. Although there are a number of problems with this technique (reviewed by Wallace 1970), it often provides the only estimates available for large sections of the country; indeed, the primary aim of the survey is to monitor birds on a regional basis.

The data which will be used for northwest birds consist of the 60 roadside surveys taken in June 1974 in Oregon, Washington, and Idaho. The raw numbers for each count are simply the numbers of individuals of each species seen. Overall, there were 210 species and about 45,000 individuals. In order to answer the questions posed above, this mass of numbers must be reduced in an orderly fashion. This will be done by means of cluster analysis of similarity coefficients, a technique taken from numerical taxonomy (Sokal and Sneath 1963) that has been employed by a number of ecologists (e.g., Thilenius 1972, West 1966, Kaesler and Cairns 1972). Essentially, the method will objectively define avifaunal regions based on the species and relative numbers seen on roadside counts. No "indicator" species receive more weight than a rare or accidental one. This avoids any bias or preconceived notion of what these regions and relationships "should" be.

The first step in this analysis is to select a measure of similarity between two counts. Horn's (1966) index of overlap (R_o) is employed because it considers not only the number of species in common, but also the way in which individuals are distributed among those species. It is given by:

Table 1.--Species of birds associated with the Pacific Northwest shrubsteppe. Habitat preferences are shown, along with crude estimates of abundance. Some species listed as residents (e.g., most falconiforms) may require trees for nesting, but are not necessarily restricted to riparian habitats. This list has been prepared from data of Dumas (1950), Booth (1952), Hudson and Yocum (1954), Peterson (1961), Larrison and Sonnenberg (1968), and Olendorff (1973).1/

Status	Species	Bunchgrass	Sagebrush
Permanent Residents	Marsh hawk (*Circus cyaneus*)	+	-
	Red-tailed Hawk (*Buteo jamaicensis*)	-	-
	Swainson's Hawk (*Buteo swainsoni*)	-	-
	Sharp-tailed Grouse (*Pedioecetes phasianellus*)	-	-
	Sage Grouse (*Centrocercus urophasianus*)		-
	Chukar (*Alectoris chukar*)	+	+
	Ring-necked Pheasant (*Phasianus colchicus*)	-	+
	Gray Partridge (*Perdix perdix*)	-	-
	Short-eared Owl (*Asio flammeus*)	+	-
	Horned Lark (*Eremophila alpestris*)	++	-
	Black-billed Magpie (*Pica pica*)	+	+
	Common Raven (*Corvus corax*)		-
	Common Crow (*Corvus brachyrhynchos*)	-	-
	Western Meadowlark (*Sturnella neglecta*)	-	++
Summer Residents	Prairie Falcon (*Falco mexicanus*)		-
	Long-billed Curlew (*Numenius americanus*)	+	
	Mourning Dove (*Zenaida macroura*)	+	+
	Borrowing Owl (*Speotyto cunicularis*)	+	+
	Common Nighthawk (*Chordeiles minor*)	+	+
	Barn Swallow (*Hirundo rustica*)	-	+
	Sage Thrasher (*Oreoscoptes montanus*)		+
	Loggerhead Shrike (*Lanius ludovicianus*)	-	+
	Grasshopper Sparrow (*Ammodramus savannarum*)	-	
	Vesper Sparrow (*Pooecetes gramineus*)	+	-
	Lark Sparrow (*Chondestes grammacus*)	-	-
	Black-throated Sparrow (*Amphispiza bilineata*)		-
	Sage Sparrow (*Amphispiza belli*)		++
	Brewer's Sparrow (*Spizella breweri*)		+
Winter Residents	Rough-legged Hawk (*Buteo lagopus*)	-	-
	Northern Shrike (*Lanius excubitor*)	-	-
Migrants	Ferruginous Hawk (*Buteo regalis*)	-	-
	Golden Eagle (*Aquila chrysaetos*)	-	-
	Merlin (Pigeon Hawk) (*Falco columbarius*)		-
	Sandhill Crane (*Grus canadensis*)	-	-
	Common Flicker		-
	(Red-shafted) (*Colaptes auratus*)		-
	Mountain Bluebird (*Sialia currucoides*)		+
	House Finch (*Carpodacus mexicanus*)		-
	American Goldfinch (*Spinus tristis*)	-	-
	Savannah Sparrow (*Passerculus sandwichensis*)	+	+
	Dark-eyed Junco (*Junco hyemalis*)		+
	White-crowned Sparrow (*Zonotrichia leucophrys*)	+	++
	Song Sparrow (*Melospiza melodia*)		++

1/ Abundance Key: Abundant ++, Common +, Uncommon -

Habitat Types: Bunchgrass - dominated by *Agropyron* or *Festuca*, shrub coverage less than 5%;
Sagebrush - dominated by *Artemisia*, shrub coverage exceeding 5%.

$$R_o = \frac{\Sigma(x_i+y_i)\ \ln\ (x_i+y_i)-\Sigma x_i \ln\ x_i-\Sigma y_i\ \ln\ y_i,}{(X+Y)\ \ \ln\ (X+Y)-X\ \ln\ X\ -\ Y\ \ln\ Y}$$

where x_i is the number of individuals in the i^{th} species in one collection, y_i is the number of individuals in the i^{th} species in the other collection, and X and Y are the total individuals in each collection. If the calculations are done in frequencies (as has been done here by converting the raw data), X=Y=1 and x_i and y_i represent the proportions of species i in the respective samples. This index ranges from 1 (complete similarity) to 0 (complete dissimilarity), but is generally expressed as a percent (range 0 to 100).

The next step is to calculate R_o between all pairs of counts to form a similarity matrix. Routes which share many of the same species in much the same proportions will be highly similar (high R_o); those with few species in common will be much less similar

The resulting matrix is then subjected to weighted pair-group cluster analysis (Sokal and Sneath 1963) as follows:

(1) the two counts with the highest similarity form the first cluster (A+B);

(2) the new similarities between this cluster and each of the remaining counts (Q) are calculated using the Spearman sums of variables method, where,

$$r_{(A\ +\ B)Q} = \frac{r_{AQ} + r_{BQ}}{\sqrt{2\ +\ 2\left(r_{(A\ +\ B)}\right)}},$$

where r_{xy} is the similarity between unit X and unit Y;

(3) the new cluster is now considered a single unit and steps (1) and (2) repeat until all counts have been clustered.

In a similar study, Grant (1971) has shown that the weighted pair-group clustering method is very efficient for ecological data such as these. Sokal and Sneath (1963) suggest the use of Spearman's sums of variables method over a simple average when using similarity coefficients that are non-linear and, hence, not directly additive.

The relationships resulting from a cluster analysis are presented in a dendrogram such as figure 1. The horizontal axis is scaled in units of R_o; the junction of clusters along

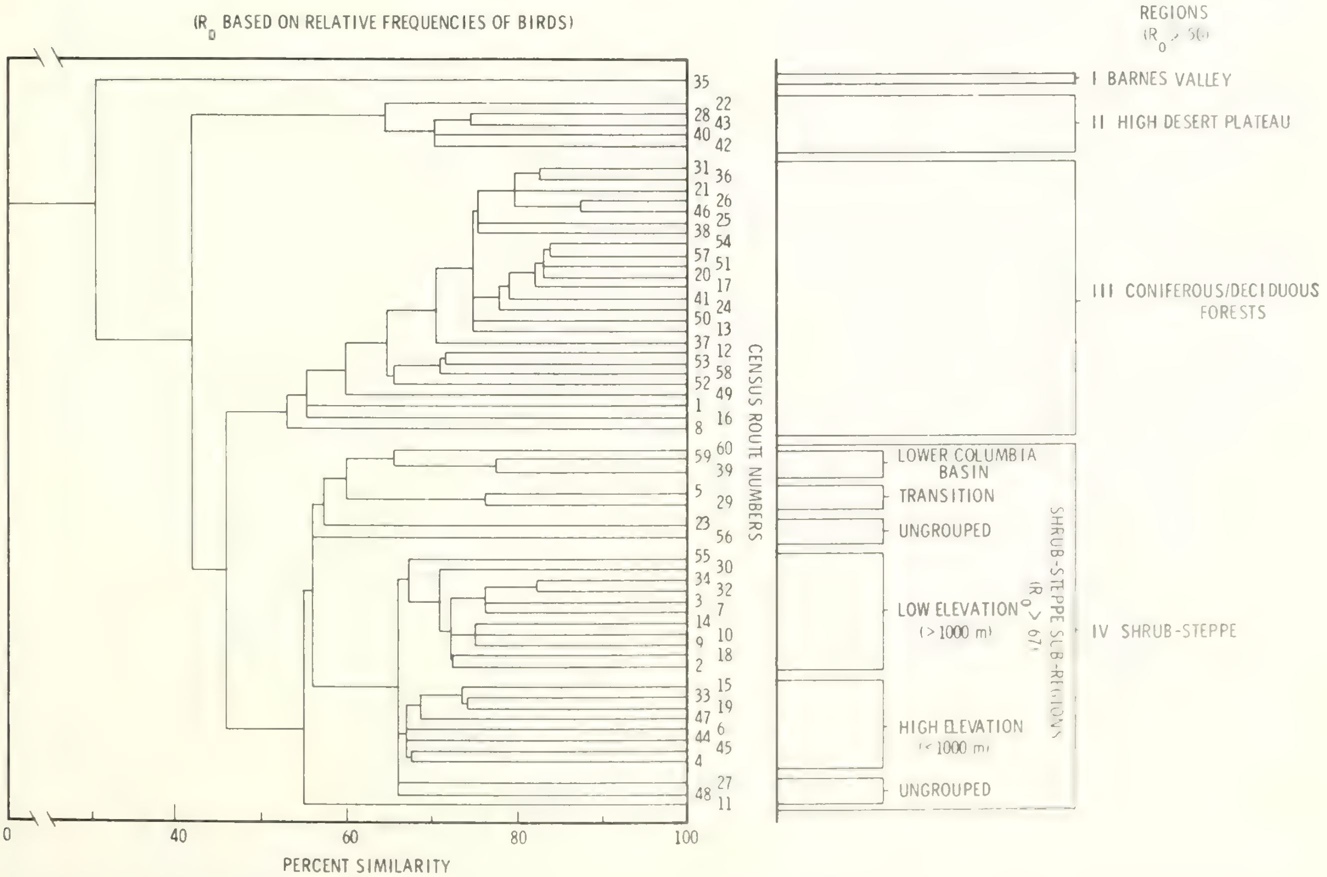

Figure 1.-- Dendrogram of roadside count relationships of northwestern areas, determined by cluster analysis based upon similarity in bird species composition (see text).

this axis indicates that all units which branch to the right are similar at that R_o value. The vertical axis has no scale but merely serves to separate the units.

While these procedures may appear rather esoteric, they are a powerful tool in condensing masses of distributional data into recognizable patterns, which are then amenable to interpretation.

The relationships resulting from clustering roadside counts of northwest birds appears in the dendrogram of figure 1. The similarity level at which we wish to define groups as "avifaunal regions" is arbitrary, and there are unfortunately no methods currently available to test for statistical differences between groups based on R_o (but see Garrett and Steinhorst 1976). Whatever level is chosen, however, must be applied uniformly. For this analysis, $R_o = 50$ seems an appropriate level to define our regions; that is, any combination of counts which have $R_o \geq 50$ among themselves and $R_o < 50$ among all others, are an "avifaunal region." This seems a reasonable level since it represents the mid-point between complete similarity and complete dissimilarity.

At this level, four distinct regions are formed. These regions are geographically delimited in figure 2. Region I consisted of a single, very distinct count which contained a number of waterfowl not seen elsewhere, and is presumably associated with one of the many desert lakes of the area. Region II was composed of five counts in the high desert plateau and Ponderosa Pine Parklands in central Oregon. The deciduous forests of the western valleys and the coastal areas, and the coniferous forests in the mountains of all three states formed the third distinct cluster, Region III, and encompassed 26 survey routes. The shrubsteppe formed the fourth distinct region, consisting of 28 routes in southeastern Washington, eastern Oregon, and southern Idaho. The limits of the shrubsteppe avifauna as defined by this method coincide closely with the limits of the shrubsteppe defined floristically. In answer to the first question posed at the beginning of this section, then, it appears that there is an avian community associated with the shrubsteppe that is distinctly different from those surrounding it.

Are the communities in this shrubsteppe region measurably different from those that comprise the other avifaunal areas? Table 2 summarizes a variety of community attributes averaged over all of the surveys within each region. Several of the differences observed were statistically significant. Species diversity, the attribute most often used to summarize community composition in one number, was significantly lower in the shrubsteppe than in both the other regions. This reduced diversity was generally associated with a reduction of the evenness of species relative abundance distributions (implying increased dominance by fewer species), but could also be attributed to a reduction in the total number of species when compared with the forested region. Differences in the average number of individuals censused in each region were not significant.

Although only data from 1974 were used

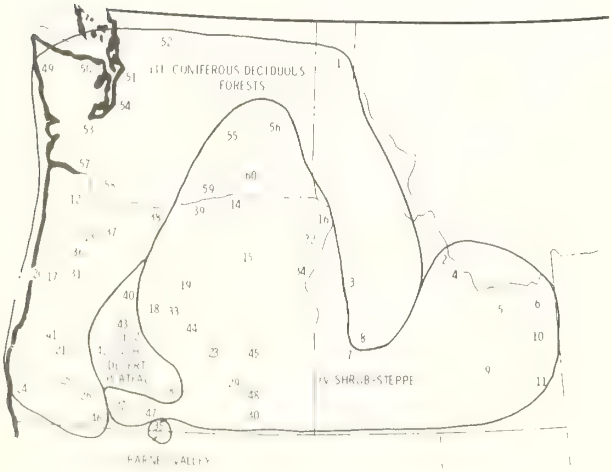

Figure 2.-- Avifaunal regions of the Pacific Northwest, based on cluster analysis of roadside counts (see fig. 1 and text). Isopleths encircle areas of equal or greater avifaunal similarity.

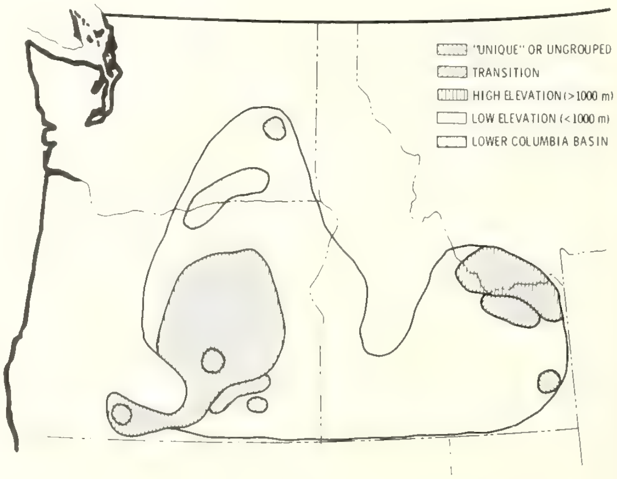

Figure 3.-- Avian communities within the shrubsteppe region of the Pacific Northwest, based upon cluster analysis of roadside counts (see figs. 1 and 2, and text).

Table 2.--Average community attributes of the three major avifaunal region of Oregon, Washington and Idaho.

Region (number of samples)	Attributes				
	Number of Individuals	Species Richness	Species Diversity	Species Evenness	Annual Turnover
II. "High Desert Plateau" (5)	518	50	3.22	0.82	0.15
III. Coniferous/Deciduous Forest (25)	606	52	3.28	0.84	0.15
IV. "Shrubsteppe" (29)	706	41	2.74	0.75	0.17

to define the regions, many of the survey areas had been censused for several years. This allowed us to estimate the annual turnover in community composition and structure within each of the regions. Quite simply, turnover has calculated as one minus the R_o-similarity between two successive years at each site. Again, this measure takes into account variation not only in species presence/absence, but also their relative abundances. Interestingly, turnover rates do not differ significantly between the presumably "stable" forested regions and the climatically "unstable" shrubsteppe. Overall, however, it seems that the composition of communities is measurably different between the shrubsteppe and the other regions.

Further examination of the dendrogram of figure 1 suggests that there are different avifaunal communities within the shrubsteppe. Again, the level at which these sub-regions are defined is arbitrary, but it appears that uniformly applying a level of $R_o = 67$ (two-thirds similarity) will yield the most information with the least distortion. The sub-regions thus formed are pictured in figure 2.

Two routes in eastern Idaho and six in east-central Oregon form a well-defined cluster. Geographically these sites are all located in shrubby or parkland areas at moderate to high elevations (900-1500 m) and are phenologically quite different from other counts in the region both with respect to climate and avian activity patterns. In sage sparrows, for example, migration and onset of reproductive acticity are delayed over two months in this region in Oregon as compared to areas in eastern Washington 400 km to the north.

This high altitude sub-region is contrasted with the next main cluster consisting of 11 routes throughout all three states, all of which are in shrubsteppe areas at elevations of less than 900 m.

Between these two high and low elevation sub-regions fall two other clusters. One consists of three routes in the lower Columbia Basin, an area dominated by dry-land wheat fields and the remnants of the *Artemisia*/*Agropyron* shrubsteppe. Included in this sub-region is the Arid Lands Ecology Reserve from which most of the data presented in other sections are derived. The other cluster is split in two: one route in southeastern Oregon, one eastern Idaho; both might be considered transitional between the high and low elevational clusters.

There are five routes which may be considered "unique", and these are so indicated in figure 3. Cursory re-examination of the raw data suggests why these routes are different: (route 11) high proportion of California and Franklin's gulls, sandhill cranes; (route 23) many mountain bluebirds; (routes 27 and 48) numerous shorebirds, waterfowl, and marsh-associated passerines, with each count having different mixtures; (route 56) although otherwise similar to nearby routes, relatively high numbers of great horned owls were seen here. Thus, in answer to the second question, there do appear to be distinct avian communities within the shrubsteppe region.

As with the major regions, we may examine differences among areas within the shrubsteppe. Average community attributes for these areas are presented in Table 3. Again, no significant variation was noted among the numbers of individuals censused, however, the high-elevation subgroup evidenced higher species diversities than all of the other sub-regions. The relatively lower diversity of the low-elevation subgroup was a function of decreased evenness; that of the lower Columbia Basin and transition area was correlated with decreased species richness (number of species). Although their diversities were similar, the lower Columbia Basin contained significantly fewer species than the transition zone. While perhaps classifiable as the most depauperate community, the lower Columbia Basin had a significantly lower turnover rate than the high-elevation subgroup.

Table 3.--Average community attributes of the four sub-regions within the "shrubsteppe" of Oregon, Washington and Idaho.

Sub-Region (number of samples)	Attribute				
	Number of Individuals	Species Richness	Species Diversity	Species Evenness	Annual Turnover
Lower Columbia Basin (3)	457	21	1.76	.57	.11
Transition (2)	547	24	1.98	.63	.10
Low Elevation (11)	868	41	2.76	.75	.16
High Elevation (8)	607	49	3.23	.83	.19

The main point to be made here is that while the avifauna of the shrubsteppe of the Northwest is distinct from that of the forested regions that surround it, it is by no means homogeneous itself. The caveat is clear: management decisions made for one specific area of rangeland may be inappropriate for another.

What species are diagnostic of the shrubsteppe in general? Again, cluster analysis may provide an objective numberical method for answering this question. The details of the technique, however, are now slightly different. The data will be given the same mathematical treatment, only now in the "Q-mode" (Sokal and Sneath 1963, Kaesler and Cairns 1972). What this means is that instead of clustering routes on the basis of the species they contain, species are clustered on the basis of the routes in which they occur. Another way of viewing it is that an "ecological taxonomy" of species is being worked out, where relationships are based not on morphology but instead on habitat. These relationships will be valid, of course, only insofar as roadside counts traverse basically the same habitat type throughout their entire length.

This "Q-analysis" results in a dendrogram showing the relationships between all 210 species considered, which is much too large to be presented here. It does, however, provide some interesting information. A distinct shrubsteppe community of birds is formed around the 30% similarity level. The dominant (i.e., numerically abundant) species are the horned lark, loggerhead shrike, marsh hawk, sage thrasher, and Brewer's and sage sparrows. Included in lesser abundances are the grasshopper and lark sparrows, sage grouse, golden eagle, ferruginous hawk, paririe falcon, and black-throated sparrow. Birds missing from this cluster but otherwise abundant in the shrubsteppe (see Table 1) include the western meadowlark, black-billed magpie, chukar, vesper sparrow, common nighthawk, and mourning dove. This suggests that birds of the former group are more or less restricted to the arid shrubsteppe habitat type (at least in Oregon, Washington, and Idaho), while the other is composed of more generalized, widespread species.

Thus, in answer to the third question, there are indeed certain species characteristic of the shrubsteppe. Areas within the shrubsteppe thus are characterized not only by slightly differing but distinctive species assemblages, but more often than not by at least some species which are more or less indigenous to or at least characteristic of this habitat type. More detailed studies now underway in our group will provide means to discern which of these species may act as "indicators" of more-or-less "natural" shrubsteppe conditions, and which may be "invaders" or "weedy species" that increase in abundance as a consequence of habitat distrubance (see below). But in any event, management options that are developed with regard to nongame birds in these regions should probably emphasize these "characteristic" species, especially the dominant forms.

Winter

Few quantitative data have been published for winter populations of birds in the shrubsteppe. Bellamy and Drake (1971) surveyed an area in northeastern Oregon and estimated only a little over 100 birds per km^2. Most of these are magpies (17.3km^2), song sparrows (17.3), and pheasants (12.4). Few meadowlarks were counted (4.9), and horned larks were only seen once in eight trips.

The Audubon Society's annual "Christmas Counts" of 1969-1973 for typical shrubsteppe sites are summarized in Table 4. These sites were selected on the basis of their habitat description (Am. Birds 1972): Tri-Cities, Table 4.--Summary of "Christmas Count" data for groups of important shrubsteppe birds, 1969-1973. Data extracted from American Birds/Audubon Field Notes. See text for habitat description of count areas. Data are expressed as the five-year average of the number of birds seen per hour per observing party, with the range in parentheses.

	Tri-Cities	Boise	Pocatello	Malheur
Raptors	1.1 (0.5- 1.3)	.7 (0.3- 0.9)	1.0 (0.5- 1.4)	3.0 (0.9- 5.4)
Galliformes	4.9 (2.8- 6.9)	6.1 (4.0-10.9)	1.5 (0.8- 2.6)	7.0 (2.4-18.5)
Corvids	3.9 (1.1- 5.1)	3.0 (1.0- 4.2)	7.3 (2.8-14.4)	4.3 (1.1-11.2)
Horned Lark	1.5 (0- 7.4)	0.2 (0- 1.2)	8.1 (0-27.5)	0.3 (0- 1.0)
White-crowned Sparrow	7.6 (3.0-13.7)	1.4 (0.6- 2.2)	0.2 (0.1- 0.7)	- (0)
Song Sparrow	1.0 (0.4- 1.8)	1.1 (0.5- 1.6)	1.9 (0.7- 3.9)	0.3 (0- 0.7)
Juncos	7.0 (0.9-13.3)	9.3 (0-18.2)	1.5 (0.6- 3.9)	1.4 (0.5- 3.9)
Western Meadowlark	0.6 (0.2- 0.9)	0.1 (0- 0.4)	0.2 (0- 0.7)	- (0)

Washington, 40% sage and sand; Boise, Idaho, 50% sagebrush, Pocatello, Idaho, 70% arid hills; and Malheur National Wildlife Refuge, Oregon, 86% sage uplands. Data for waterfowl and other "inappropriate" species are not presented here.

The most consistently observed birds were the raptors, galliforms, and corvids, which are all generally permanent residents here, and song sparrows, which usually migrate throughout the region. Less consistently seen were juncos and white-crowned sparrows, which are also migratory here. Low numbers of meadowlarks were seen. These numbers are similar to those of Bellamy and Drake (1971). Horned larks showed the greatest variability, yielding both the highest and lowest numbers recorded in the table (27.5 - 0.0). This suggests that these birds are generally seen either in large flocks or not at all. To a lesser extent this appears true in the other small passerines. Cody (1971) has speculated on flock formation in small birds and suggests that flocking activity increases in areas of decreased food supply. The lower productivity of this arid region might possibly be a factor operating here.

The few roadside counts that we have conducted during winter at our primary study locations in southeastern Washington, east-central Oregon, and northern Nevada all show the same trends: considerably reduced species diversity as a result of both lowered species richness and evenness. Never more than 10 species have been observed on any single count, in each case, and anywhere from 55% to 81% of the individuals observed belong to a single species, the horned lark. It should be noted, too, that on two counts performed during inclement weather (cold, blowing snow), no birds were recorded. Overall, it appears that wintering avifaunas over most of the Northwestern shrubsteppe are sparse, both in species occurrence and in abundances.

FEEDING RELATIONSHIPS

Birds are tied into the functional operations of ecosystems largely through their trophic relationships. These determine the positions and roles of bird populations in energy flow and nutrient cycling, and mediate their effects on and responses to prey population dynamics. To the extent that bird populations assume economic importance in managed ecosystems (e.g., agriculture), this is frequently a product of their consumption of food resources valued by man (Wiens and Dyer 1977).

While it is inappropriate for us to review all these aspects of avian feeding relationships in western rangelands here, a

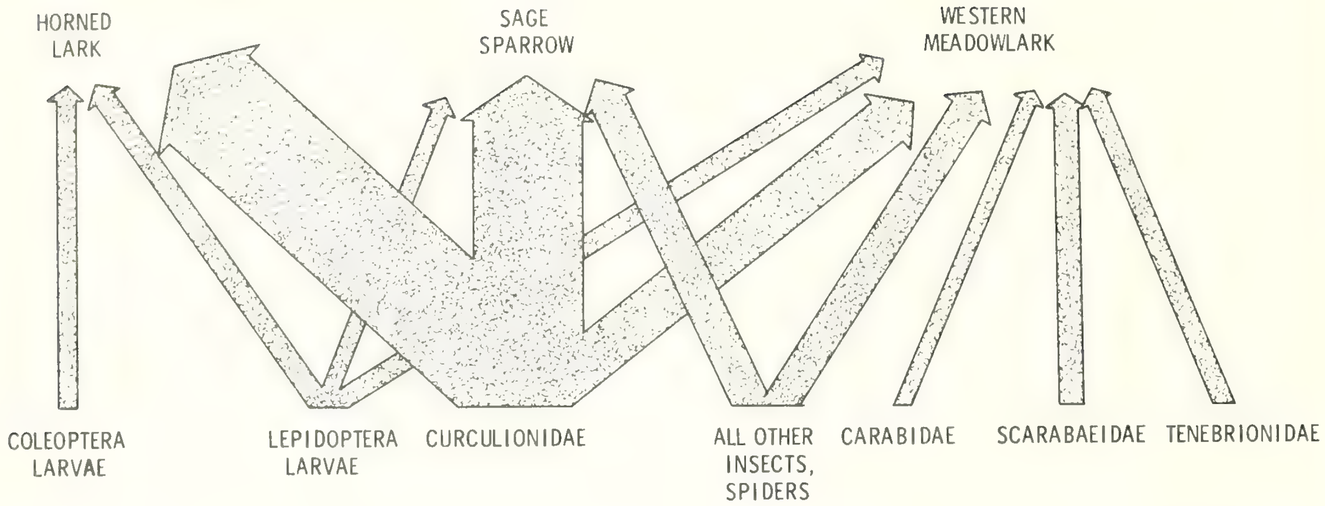

Figure 4.-- Generalized food web for the late spring breeding bird community on the ALE Reserve, southeastern Washington. Arrow widths are proportional to the percentage of the total dry weight each prey taxon contributed to each species' diet. Taxa contributing less than 10% to the total diet of any species are omitted.

general summary of the diets of the major species breeding in the ALE Reserve in southeastern Washington may provide a perspective for these species in this system. These studies are reported in greater detail by Rotenberry (MS). During spring, all three species breeding in shrubsteppe habitats (Horned Lark, Western Meadowlark, and Sage Sparrow) are highly insectivorous; about 75% of the early spring diet is composed of various insects, increasing to nearly 100% later on, and decreasing to around 10% in winter (when only Horned Larks remain in any numbers). The most common insect prey were coleopterans, particularly weevils (Curculionidae) and beetle larvae (mostly Tenebrionidae). Ants, grasshoppers, small hemipterans, lepidopteran larvae, and spiders were also consistently represented in the samples, although generally in small quantities. The general patterns of the dietary relationships in late spring samples are displayed in figure 4.

Grass seeds and forb seeds were important items only in winter diets of Horned Larks. These birds seem to switch from grass seeds in October to forb seeds in November, perhaps reflecting the fact that the majority of gramoids in this habitat are cold-season grasses whose seeds germinate in the fall, and hence become unavailable to the birds later in winter. Most of the forbs, especially tumbleweeds (Salsola kali), whose seeds form the major proportion of the forb seeds consumed by the birds, do not germinate until early spring.

These results, and our experience in the field during several years' intensive research, prompts us to comment on a report recently issued by Goebel and Berry (1976). They conducted feeding trials on birds occurring in "depleted rangeland" in eastern Washington. We quote their conclusions:

> "This study substantiates that seed of desirable forage grass species is preferred by birds over the annual grass species abundantly found in the area. Thus, local bird preferences could indirectly contribute to the degredation of a range community. While domestic grazing animals may be consuming established plants of the more palatable species, birds may intensify the degradation of the community by consuming seed that is produced by the native bunchgrass or desirable forage species."

We feel these conclusions are totally unwarranted. The "tests", conducted during early spring (after the major germination periods of most native grasses), presented measured quantities of seeds of several species to the birds "cafeteria-style" on a feeder 1.3 m above the ground. Consumption was gauged by weekly samplings of the seed remaining. There were therefore no direct observations of feeding by the birds, and while a crude "census" of birds present in the area was conducted (in August and in March!), there was no way of knowing which species actually removed the seeds (if in fact they were removed by birds). Few of the bird species

Table 5.--Characteristics of breeding avifaunas in shrubsteppe habitat on the ALE Reserve, southeastern Washington, before and following a range fire in August 1973 destroyed the shrub cover.

Attribute	Pre-Burn			Post-Burn			
	1971	1972	1973	1974		1975	
				Unburned1/	Burned	Unburned1/	Burned
Total Density (birds/km^2)	291	206	230	227	*223*	230	*157*
Species Diversity2/	1.11	1.12	1.03	1.08	*0.99*	1.03	*0.99*
Dominance	0.49	0.46	0.49	0.42	*0.56*	0.43	*0.51*
Total Biomass (kg/km^2)	11.51	7.71	9.34	9.87	*9.94*	8.76	*8.33*
Biomass Diversity	1.28	1.09	1.01	0.97	*0.93*	1.06	*0.80*
Average Weight (g/indiv.)	39.6	37.4	40.6	43.5	*44.6*	38.1	*53.1*
Number of Species	4	4	3	3	*3*	3	*3*

1/ In most respects identical in vegetation structure and bird community composition to pre-burn 1973. (8% coverage by Artemesia; similarity based on species abundances $R_o = .98$)

2/ Calculated by $-\Sigma p_i \ln p_i$, where p_i = proportion of all individuals belonging to the i^{th} species.

3/ Calculated as the relative proportion of the most abundant species present. For pre-burn and unburned plots this was sage sparrow. For burned plot this was horned lark.

characteristic of such rangelands will feed at such elevated sites (a feeding location never encountered in natural seetings), so the relevance of these tests to natural situations must be questioned. Actually, most of the birds recorded in this "census" are not even granivorous (hawks, kingbirds, swallows, etc.). Further, the seeds that were "preferentially removed" were the smallest ones --- exactly those that one would predict from ecological theory would be the last to be consumed by birds of the size that winter here (e.g., Willson and Harmeson 1973) and the first that one would expect to disappear from the physics of particle movement by wind. To propose from such a study that birds may seriously impair reseeding efforts on over-grazed rangelands and "contribute to continued degradation of range communities by their seed diet preferences" is dangerous nonsense.

EFFECTS OF HABITAT ALTERATIONS

Western rangeland habitats are subjected to a variety of disturbances, some natural and many imposed by man. To the extent that these disturbances influence the availability of food supplies or nesting sites, the microclimatic patterns, or the overall structure of the habitat, bird populations and communities are affected. In the more arid rangelands of the West, natural recovery or "repair" following disturbance is extremely slow (Wiens 1974, Noy-Meir 1973), and effects may persist over many generations. Obviously, wise management of nongame bird habitats must consider the effects of habitat alterations of various sorts.

One disturbance of rangeland habitats occurs as a result of wildfires. These are usually a result of lightning, often in late spring or summer, and while the frequency of range fires may be lower now than formerly as a result of improved detection and control, they still do occur. In August 1973 a lightning-caused range fire burned several thousand hectares of the ALE Reserve, including most of one of the plots on which we had been conducting breeding censuses since 1971. The fire removed nearly all of the shrubs, reducing shrub (mostly Artemisia) coverage from roughly 8% to less than 1%; the vegetation following the burn consisted primarily of Agropyron. In the breeding season following the burn, total density and biomass of bird populations did not differ from those in nearby unburned habitat (Table 5), although in 1975 density was somewhat lower in the burned area. Yearly variation prior to the burn was considerable, however, so it is uncertain how much of this difference is directly attributable to the habitat change.

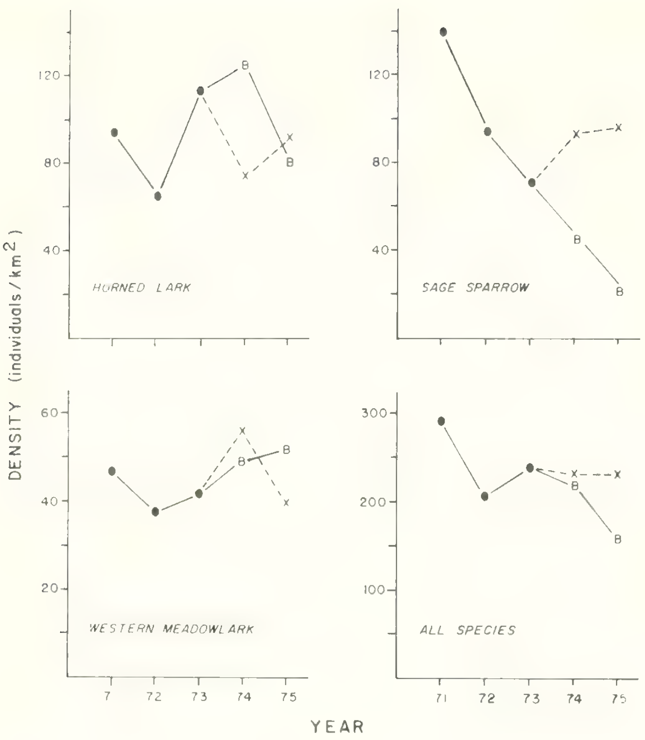

Figure 5.-- Breeding densities of bird in shrubsteppe plots at the ALE Reserve, southeastern Washington, 1971-1975, illustrating the effects of a wildife in August 1973 that destroyed the shrub cover.

There is no doubt, however, that habitat alterations accompanying the burn changed the relative abundances of the species present. Sage Sparrows decreased to low densities while Horned Lark abundance increased, especially in the season directly following the burn (Figure 5). This undoubtedly reflects the differing relationships of these species to the presence of shrub cover (see below). Horned Larks replaced Sage Sparrows as the dominant breeding species on the plot, and this replacement also produced shifts in biomass distribution in the avifauna, as indicated by the reduction in biomass diversity and the increase in the weight of an "average" individual bird (Table 5). Despite these changes in the relative abundances of species and the structuring of breeding avifaunas, the species composition on the plot has remained unchanged. Studies that attempt to document the effects of habitat alterations on rangeland avifaunas, therefore, must consider more than just the species listed for a site or region.

In general, the sensitivity of shrubsteppe avifaunas to fire seems to be closely tied to the sensitivity of sagebrush or other dominant shrubs. Mature Artemisia/Poa stands contain insufficient litter or mulch to support any but the hottest fires, and are largely fire-resistant. Artemisia/Agropyron or Agropyron/Poa vegetation burns readily, and virtually all sagebrush is removed. To the degree that bird species respond to changes in the coverage of sagebrush, the community as a whole will be affected. These different sensitivities of vegetational associations to fire, and the consequent effects upon the avian communities, should be considered in the framing of management tactics for grazing that propose seeding of various grasses into an existing sagebrush-dominated habitat.

Brush control through spraying with herbicides or mechanical removal is practiced widely as a form of "range improvement" in western rangelands (Vale 1974, Pechanec et al. 1965), and because of the large scale of these operations this represents a more important form of nongame bird habitat alteration than wildfire. Several studies have examined the effects of sagebrush control on nongame bird populations. In Montana, Best (1972) examined the responses of Brewer's and Vesper sparrows to control spraying of sagebrush with 2,4-D. Treatment that produced a partial kill of sagebrush produced no significant change in the population density of either species, but at total kill levels there was a 54% reduction in Brewer's Sparrow densities the year following spraying. Five years after spraying Brewer's Sparrow was virtually absent from this plot (Pyrah and Jorgensen 1974). Vesper Sparrow densities on the total kill plot were unaffected, and these species differences reflect the dependence of Brewer's Sparrow on shrub cover for nesting, that of Vesper Sparrows on ground cover. The diets of both species contained a greater proportion of seeds on the sprayed than on the unsprayed plots, but in general the birds responded to the habitat changes following spraying by varying the relative quantities but not the varieties of prey consumed. In a study in Wyoming, Schroeder and Sturges (1975) censused Brewer's Sparrows on unsprayed plots and several sprayed plots. Densities were reduced by 67% 1 year after spraying, and by 99% 2 years after treatment. This study also examined the potential direct effects of herbicidal treatment, by spraying several sagebrush plants containing active nests and the surrounding 5 ft radius with 3lb/acre acid equivalent 2,4-D. The sagebrush leaves became dry and brittle within 2 weeks of the treatment, but remained on the plants for 2 months, providing shade and shelter until after the young had fledged. Growth rates and survival of young in sprayed and unsprayed nests were similar, and there was no evidence of a direct reduction in nesting success by the application of the herbicide.

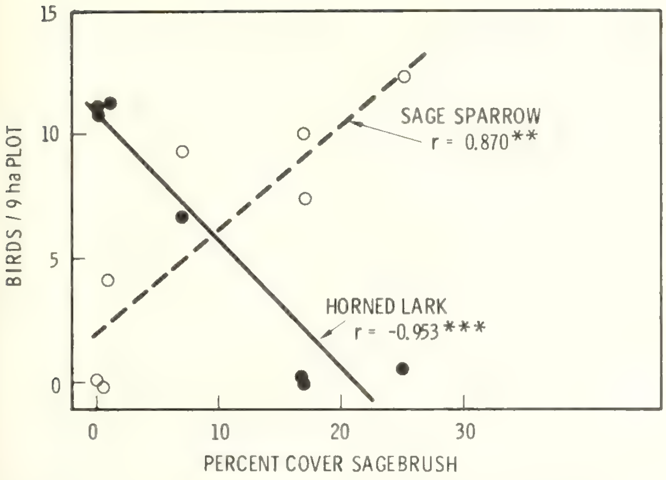

Figure 6.-- The relationship between the densities of horned larks and sage sparrows and percent cover of sagebrush on census plots at the ALE Reserve, southeastern Washington, April/May 1974. ** implies statistical significance at the 0.01 level; *** = $p < 0.001$.

These studies generally confirm the conclusion that species populations in western rangelands are at least moderately resistant to small-scale habitat perturbations, especially if the basic structural configuration of the vegetation is not markedly altered. Most evident modification of the environment, including the removal or severe reduction of shrub cover, may have profound effects on species abundances, while not necessarily altering total avian densities or biomass. Obviously, species that are closely tied to shrubs in their habitat utilization are most susceptible to the prevalent forms of rangeland habitat alteration. Brewer's Sparrows react in this manner. Our studies at the ALE Reserve indicate additional species relationships to shrub (sagebrush) coverage (fig. 6). There Sage Sparrow densities were directly correlated with increasing sagebrush coverage, while Horned Lark densities followed an inverse relationship. For the Sage Sparrows, the data appear somewhat curvilinear, density rising rapidly with initial increases in sagebrush coverage, then continuing to increase at a reduced rate beyond some "threshold" sagebrush coverage. These two species appear to differ as well in the nature of the response to sagebrush coverage. As shrub cover increased, Sage Sparrows increased their density by decreasing the size of their territories (1.8 to 1.0 ha) while increasing the number of territories per plot (4.7 to 6.2). Horned Lark territories remained unchanged in size as sagebrush coverage increased (2.0 to 2.1 ha), but there were simply fewer of them (3.4 to 0.3 per 9 ha plot) (Rotenberry MS). Densities of Western Meadowlarks were uncorrelated with shrub cover, perhaps reflecting their larger areas of activity.

CONCLUSIONS

When confronted by wildlife managers with questions requiring immediate answers, most non-management biologists temporize, exclaiming that more basic research is needed before the necessary answers may be provided. While our own research clearly indicates much remains to be learned, we nevertheless feel that the data presented here, both from our studies and those of others, do allow us to make some predictions regarding the eventual outcome of management decisions.

We have shown that the avifauna of the shrubsteppe of the Pacific Northwest is different from that of the biomes surrounding it. Therefore it is not unreasonable to expect distinct differences in their responses to perturbations; indeed, even the nature of the major disturbances is different (grazing vs. logging). Given that certain species are diagnostic of the shrubsteppe and occur there regularly, we have suggested that several are more or less restricted to this habitat type, and it is on these that attention should be focused. In particular we would recommend the use of the sage thrasher and a variety of sparrows (the sage, Brewer's, lark, and black-throated) as potential "indicator" species to monitor the effects of rangeland manipulations.

Our feeling is that community composition will respond to habitat alteration mainly through individual species' responses to changes in the coverage of brush. Although a positive statistical correlation between species abundance and brush coverage has only been demonstrated for sage sparrows (see figure 5), it is quite clear that large-scale removal of brush will result in the decline of the other four "indicator" species also. We further expect the void left by this reduction to be filled mainly by horned larks, although if the coverage of tall grass remains high we might anticipate a rise in the numbers of the opportunistic grasshopper sparrow.

Where we clearly lack the necessary information to make sound management decisions is with regard to the effects of manipulations that alter the food base upon which the birds depend. Few long-term studies have dealt with the effects of insect control (either indirectly through the reduction of potential prey items or directly through the toxic effect of insecticides on birds; but see McEwen et al., 1972, for shortgrass prairies), and none have been done in the shrubsteppe. Since we have noted that most of the dominant birds are largely insectivorous during the breeding season, the possibility of adverse changes in the trophic dynamics of the community exists. Not only do we lack adequate data for insect abundances, but in many cases we lack even the basic information regarding bird diets.

We have attempted to provide a base from which some predicitions may be made regarding the outcome of potential management practices. Some of these data strongly suggest that major habitat alteration, such as the removal of sagebrush from large areas, will result in the reduction or elimination of certain species from these areas. It is here that, regardless of our personal feelings, we must pass the buck: ultimately it is the range manager who must weigh the benefits vs. the cost and make the decision. It is a value judgment of much importance.

ACKNOWLEDGMENTS

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FOREST AND RANGE WILDLIFE HABITAT MANAGEMENT: ECOLOGICAL PRINCIPLES AND MANAGEMENT SYSTEMS[1]

Hugh Black, Jr.[2] and Jack Ward Thomas[3]

Abstract.--Basic principles that govern ecosystems, components of plant communities, their attendant successional stages and their relationships to habitat are discussed. Timber and range management practices can modify plant communities in forest and range land ecosystems. Basic wildlife management principles and management systems that guide and modify timber and range management activities are shown. Well coordinated management can simultaneously achieve several predictable resource goals.

INTRODUCTION

Each plant community and/or successional stage within that plant community provides habitat for different groups of bird species (Kricher 1973, Shugart and James 1973 and Martin 1960. Variability in species and numbers present is a result of the difference in food, cover, and water available and in the structural characteristics of the habitat with each species having unique requirements (Von Haartman 1971 and Hilder 1965). Land management must insure that these diverse requirements are provided over time, lest we find ourselves in the business of eliminating species. General ecological principles must be understood and used to tie wildlife management to all activities that alter plant communities. We must develop the ability to make informed land management decisions that yield predictable results.

LAWS THAT GOVERN ECOSYSTEMS

An understanding of the basic principles, as we now understand them, that govern ecosystems is required. When these principles are overlooked, the result is chaos and land managers may find themselves saying, "I didn't anticipate that happening".

Charles Darwin (1859:462) in Origin of the Species stated, "It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us".

The First Law of Thermodynamics: Energy is neither created nor destroyed, although it may change form.

An organism gets energy from ingested food. As food is utilized, chemical energy is converted into energy of motion. Warm blooded species convert chemical energy into heat energy to regulate body temperature. If energy is not used in either of these two ways, it is stored for later use. Or in other words, the amount of chemical energy used is equal to the amount of energy of motion, heat produced, and energy stored.

This is true for ecosystems as well as organisms. Light is the basic form of energy. Energy that enters the earth's surface as light is balanced by energy that leaves as heat radiation. Without energy transfers, there would be no ecosystem.

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The Second Law of Thermodynamics: The Usefulness of Energy is always being consumed, even though the energy is still present in one form or another.

Energy is most usable where most concentrated, i.e., chemical bonds in gasoline, high temperatures of steam, in the leaves of plants and the flesh of animals. There is a general tendency away from energy concentrations, and such energy cannot be recycled. An organism must ingest more than a pound of food to gain a pound of weight as energy of motion and heat are also produced. Plant communities are the producers and storers of energy for ecosystems.

The First Law of Ecology - "Everything is connected to everything else"

Each living organism is linked to many others (Commoner 1971). There are a myriad of such links in an ecosystem. Most ecosystems are complex, criss-crossed like a net, rather than simple circular paths. A net with its many knots can resist collapse, even when a strand is broken, better than a simple unbranched circle of threads. The same is true for an ecosystem, the more links - the more it will resist collapse.

See Ehrenfeld (1976) for a review of this theory that contrast the conclusions of Commoner.

The Second Law of Ecology - "Everything Must Go Somewhere"

This law simply states that there is no such thing as "waste". In every natural system, what is excreted by one organism as waste is sooner or later utilized by another. Animals need oxygen and give off carbon dioxide as waste and plants do just the opposite. Natural systems tend toward an equilibrium in this regard even though, in the truest sense, it is never achieved (Commoner 1971).

The Third Law of Ecology - "Nature Knows Best"

This law simply states that any major manmade change in a natural system has the potential to be detrimental to that system. It contradicts the idea that man can improve on nature. It recognizes that man is a part of nature. Commoner (1971:34) theorized that in effect, there are 2-3 billion years of "Research and Development" behind every living organism. The structure of natural ecosystems must be best since they have been so heavily screened for disadvantageous components. A staggering example is that if one molecule each of all possible protein types were made, together they would outweigh the observable universe. The odds are good that any such compound we could create has been previously tested in nature.

Fourth Law of Ecology - "There is no such thing as a Free Lunch"

Appropriately enough, this principle originates in economics, embodies the first three principles and says that every gain is won at some loss. An increase in one species will result in a corresponding decrease in one or more other species.

Those land managers who constantly remind themselves of these principles and act upon them, do a more prudent job of land stewardship (management). Reality reminds us that managers are often influenced by politics when making land management decisions. Political decisions do not always recognize ecological principles. This is because many people in this country are more concerned with basic needs. Amenities are less important to these people. Ecosystem stability is to many an "amenity".

Ecosystem stability is not, in the long run, an amenity. Elimination of ecosystem components tends towards less stability. Unpredictably eliminating ecosystem components should be considered poor land management. Predictable elimination of ecosystem components while having the same result, at least has the virtue of recognizing consequences. It should be recognized that nature (other than man) has and will continue to eliminate ecosystem components. Predictable increases and corresponding decreases, above viable levels, that do not eliminate components are probably neither good nor bad - they just are. The prime consideration in such cases should be whether or not the management objective is valid and has been met. The "bottom line" is that managers should be very wary of any multiple-use land management plan that promises more of all products.

Aldo Leopold summed it up well when he stated that if we intend to play with the puzzle of nature, we should be smart enough to save all the pieces.

ECOLOGICAL PRINCIPLES

This section relys heavily on the review of Gill et al. (1976).

Habitat

Habitat is composed of food, cover and water. Each species is adapted to a unique arrangement of these components. No two species requirements are precisely the same. There are a multitude of ways a plant community provides these items and a multitude of ways that animals utilize them.

Niche

A niche is that unique combination of plant community and attendant successional stage that provides a species habitat. Vertical and horizontal stratification and structure of vegetation provides a myriad of ecological niches. The removal of any vegetation strata will result in the loss of those species that use it (Kelly et al. 1975).

An ecological niche may transcend plant communities, successional stages or strata or combinations thereof. A niche may also be confined to one or a portion of a plant community, successional stage, or strata. Each niche contains the vital habitat essentials required: food, water, cover, as well as other special requirements.

Plant Communities

A plant community is an aggregation of living organisms that have mutual relationships among themselves and to their environment (Oosting 1948).

Such communities are the products of interaction between two phenomena: difference in ecologic tolerance of the plants and the heterogeneity of the environment (Daubenmire 1968). Thus, a plant community is the consequence of rigorous habitat selection that denies opportunity to all but a few of the great variety of species that reach the site.

So, the plant community is a unique arrangement and combination of plants that occur on a site influenced by soils, temperature, elevation, solar radiation, slope, aspect and precipitation.

Each plant community contains dominant plants of similar growth patterns producing predictable structures. As bird behavior patterns are well fixed, they can be associated with plant communities which meet their particular requirements for food, cover, or nesting (Graham 1967).

Biotic Community

The concept of the biotic community is important not only because plant and animal populations are interwoven everywhere, but also because there is a certain amount of conformity in their distribution over the landscape (Daubenmire 1968). This means there is predictability in plant and animal systems which in turn makes them manageable.

Plant distribution is controlled by physical environmental factors. Animal communities are usually a product of types of food and shelter afforded by the plant community, i.e., they conform to the plant community or habitat composition or structure.

The plant community provides habitat for the animal community. The animals in turn influence the plant community. Understanding these relationships is necessary to achieve increasing management sophistication for together they make up the biotic community which is the key building stone.

Succession

Plant communities are never completely stable. They evolve through transitory stages from bare ground to mature or climax vegetation - a process called succession. Rate of succession varies between each community and is influenced by many environmental factors. Disturbance can accelerate or retard succession (Meslow et al. 1975). Some natural disturbances are fire, insects, disease, erosion, wind, frost, snow, ice and impacts of native wildlife. Induced disturbance, those caused by man, are silvicultural practices, prescribed burning, revegetation, livestock grazing, and recreation use.

Primary succession refers to areas where no vegetation has grown before. Secondary succession results when normal succession is disrupted. It is this second type with which we are most concerned.

Succession is predictable and as such manageable. Regarding plant succession, management is planned disturbance. There is an animal community associated with each successional stage or condition of the plant community. Together they make up the biotic community. Then, all three communities can be said to be successional in nature.

Edge

Edges are where plant communities and/or successional stages or strata within a plant community meet. Wildlife abundance is largely a phenomenon of edges and occurs where types of food and cover come together or where their edges meet. This probably relates to the desirability of simultaneous access to more than one environmental type or the richness of border vegetation or both. Edges are most important to those animals with limited mobility but which need a diversity of plant communities and/or successional stages to fulfill their habitat requirements (Leopold 1933). Nesting birds usually have limited mobility.

Edges between two plant communities are usually the result of a change in environmental conditions such as soil type, topography, geographic features or microclimate. Edges between successional stages, excluding man's activities, are created by environmental changes such as fire, disease, flooding and erosion (Thomas et al. 1977).

Structural components of edge include type, configuration, location, length, width, height and depth (Thomas et al. 1977). In general, the more complex the edge, the greater the animal species diversity.

For the most part, edges between plant communities cannot be created. They can be altered. Type conversions are an exception, but without maintenance they tend to revert to the original plant community. Edges between successional stages can be created and altered in various patterns, providing different opportunities for amounts and type of edge and subsequent wildlife response. As such, edge can be managed with some predictability and numerous alternatives to fit land management schemes. Patton (1975) and Thomas et al. (1977) discuss simple methods to measure edge habitat and diversity.

Diversity

Diversity is the variety that exists in plant and animal communities. Habitat diversity results from both horizontal and vertical stratification of vegetation (Kelly et al. 1975). Each particular area has its own unique potential for diversity.

Numbers of species, both plant and animal, in an area is a measure of diversity. Size of habitat blocks influence the number of species present on a particular area (Gall et al 1976) and is related to diversity.

Bird species richness approaches the maximum in eastern deciduous forests with average habitat (plant community) sizes of about 34 hectares (84 acres) (Galli et al. 1976). Larger habitat blocks would probably attract a few more species while smaller ones would cause losses. Habitat blocks can become so small as to tend toward habitat homogeneity (Thomas et al. 1977).

Diversity of breeding bird species was demonstrated to increase with plant species diversity in the chaparral plant community in southern California (Nelson 1975). Nelson also found that habitats with greater plant species diversity supported greater densities of breeding birds.

Although information relating to habitat size required for each species is not yet available, and may never be agreed upon, some professional judgment is appropriate. Habitat (plant community) size is very predictable and should be considered when managing land for diversity.

Interspersion

Interspersion is a measure of how plant communities and/or successional stages are arranged on a particular area. The abundance of resident species requiring two or more cover types depends upon the degree of interspersion and amounts of such types (Kelker 1964).

A high degree of interspersion produces large amounts of edge. Increased edge will result in more habitat diversity.

Stability

Stability is a measure of the ability of the biotic community to withstand change. The more complex the ecosystem, the more successfully it can resist stress; in other words, a complex system is more stable (Commoner 1971). This relates directly to the principle that... "Everything is connected to everything else". Think of a net, the more strands there are, the less likely it is that one break will affect the purpose of the net. The same is true for an ecosystem.

Change - The Dynamics of Community Structure

Plant communities undergo constant change whether it be natural or induced by man. Changes can increase edge, which increases diversity. Complexity and stability also change constantly. These changes have a direct bearing on the type and abundance of animals that reside in a particular plant community. Some wildlife will be favored and some adversely affected by any change.

Edge and diversity are measurable. Induced change can be planned to provide habitats of various types and specific levels of diversity with, at least theoretically, corresponding levels in wildlife populations.

FOREST ECOSYSTEMS

Within the 50 states, 759 million acres support forest lands, two thirds of which is commercial (U.S. Forest Service 1965).

There are more niches available in forest, forest edge, and forest riparian communities than any other type of terrestrial ecosystem. This is primarily due to the increased stratification and diversification of plant forms. Many forest niches are much the same, regardless of whether they occur in deciduous or evergreen forests or geographical location (Blake 1926, Dirk-Edmunds 1947). Species occupying these similar niches may or may not be taxonomically related.

TIMBER MANAGEMENT METHODS

Uneven-aged forest management can be achieved several ways. Generally, it can be thought of as having more age groups represented on each acre over time. More acres of full or closed canopy will prevail. It is generally used when complete removal will result in a site too harsh to reforest within an acceptable time or when public opinion or other resource values act as constraints on drastic changes in the landscape.

In general, there is a tendency over time toward loss of diversity of plants and animals (Gill et al. 1976). This is primarily because there is a gradual loss of shade-intolerant plants and an increase in shade-tolerant plants. There is also a loss of distinct successional stages, with corresponding loss of induced edge, interspersion, and species dependent upon these habitat components. Such management will favor wildlife species adapted to multi-storied heavy canopied stands.

Even-age forest management can, if carefully planned and carried out, provide distinct successional stages properly arranged in space and time, large amounts of edge, interspersion, and greater animal species diversity and abundance.

Ideally, both even- and uneven-aged timber management will be used to achieve wildlife habitat goals. Each benefits different groups of wildlife species.

RANGE ECOSYSTEMS

Approximately 1 billion acres, or over 40 percent of the land area of the 50 States are grazed by domestic livestock. This includes 645 million acres of pasture and range land, 244 million acres of forested lands, and 66 million acres of cropland used for pasture only (U.S. Department of Agriculture 1962).

Range is defined as all land producing native forage for wild or domestic animal consumption (Society for Range Management 1964). Forage production on native ranges may vary by 300 percent for perennial and 1,000 percent for annual vegetation due largely to varying precipitation (Stoddart and Smith 1955). Temperature and moisture are critical at some time of the year.

Rangeland vegetation includes grass, forbs, shrubs, trees, and mixtures of these types. At what point a rangeland with trees becomes a forested ecosystem is not clear. Range ecosystems are usually characterized as having less stratification and diversity than forested ecosystems. There are less types of niches available than in forested ecosystems.

RANGE MANAGEMENT METHODS

Basic grazing systems recognized are: continuous (not yearlong), rotation (or alternate), deferred, deferred-rotation, and rest-rotation (Society for Range Management 1964). Each system can be expected to produce impacts on wildlife habitat conditions. The effects of livestock grazing on wildlife may be competitive, beneficial, or neutral. More importantly than whether an area is grazed is how, when, and to what extent.

Each rangeland plant community will respond differently to grazing use. Deferred rotation and rest rotation provide the best opportunity to manage for a variety of successional stages arranged in space and time to attain mutual wildlife habitat goals.

It may be that several of these methods will be combined to meet varying wildlife goals on a management area. Some goals will require livestock use, while some will be best met by non-use. Whatever grazing system(s) is employed, livestock should be a tool used in habitat management, not an end in itself.

WILDLIFE MANAGEMENT IN FOREST AND RANGE ECOSYSTEMS

Wildlife management is manipulating vegetation or animals or both to achieve specific goals. Managing forest habitats requires the ability to manipulate tree cover (Trippensee 1948). Managing range habitats requires the ability to manipulate grass and shrub cover. Vegetation alteration to produce wood, red meat, or both changes wildlife habitat. It is possible to achieve wood, red meat, and wildlife goals simultaneously with well planned on-the-ground application. Timber and range management practices can be used to insure diversity and stability of the biotic community over time and space, or to provide habitat for individual wildlife species (Giles 1962).

On-going timber and range management programs, are broad, practical, vegetational alteration tools that habitat managers must utilize if they are to achieve wildlife goals.

Each forest or range management practice has different potential to produce change. Thus, each will affect diversity and stability of a biotic community in a different manner. Thinning advances succession; overstory removal retards succession. Depending on the situation, edge and interspersion will be increased or decreased. Heavy livestock use can retard succession. Light to moderate use can advance succession. Again, edge and interspersion is either increased or decreased. Leopold (1949:262) advises, "Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise".

There is no forest or range management practice that can be considered a panacea for wildlife. Once the wildlife goals have been established, managers will have to utilize a variety of management practices, dependent upon land capability, which will vary from area to area and change with time. Flexibility is the key to achieving diverse, changing habitat management objectives.

PRINCIPLES OF WILDLIFE MANAGEMENT

Wildlife management is the science-based art of managing wildlife and their habitat, including man, for the benefit of all plants and animals in the environment (Nelson 1974). Assumed is the fact that habitat and/or populations will be manipulated to achieve some goal or management objective. Implied is the ability and managerial flexibility to do so (Leopold 1933, Trippensee 1948, Giles 1971).

Gottschalk (1975) outlined the following four general principles for resource management. They are:

1. Ecosystems should be maintained to produce consumptive and non-consumptive values on a continuing basis, ensuring present and future options while minimizing irreversible and long-term adverse effects.

2. Fail safes should be built into all management decisions.

3. Measures to conserve wildlife should avoid waste of other resources.

4. Analysis and assessment should precede planned use of wildlife with public review encouraged.

OBJECTIVES OF WILDLIFE MANAGEMENT

There are two general objectives in wildlife management - management for species richness and featured species. They may be used singly or mutually on any area. Public desire, management strategy, and level of knowledge may dictate which is used. Eventually, on all areas, both will be used together to:

1. Manage for those species in which the public is interested.
2. Manage to achieve compliance with laws such as those concerning threatened and endangered species. (1 and 2 may be the same).
3. Insure that additional species do not become threatened or endangered.

Objectives 1 and 2 are featured species management. Objective 3 is management for species richness.

On some areas, individual species or groups of species have been intentionally reduced or eliminated because of conflict with some other activity... a form of featured species management.

We must manage ecosystems in their entirety, with full recognition that all organisms play an integral part.

Progress towards objectives, whether they be for wildlife populations, segments of habitat or total habitat diversity should be measurable. Objectives toward which progress cannot be measured tend to be meaningless to land managers because they cannot achieve them and to the public because they cannot tell if the job is being accomplished.

Measurable objectives are not easy to develop. Needed data often does not exist. Yet, lack of data is no reason not to have goals. Biologists must put their professional judgment on the line to establish goals. If they don't, it is certain that a forester, engineer, range conservationist, landscape architect, or fuels manager will. These are the people who are making wildlife decisions daily, often inadvertently, as many biologists stand by complaining about not enough data. Biologists need to get together, establish interim baseline information and consensus among themselves.

MANAGEMENT SYSTEMS

Featured species or species richness management systems or both are procedures for achieving habitat diversity. The systems differ as you move from one area to another and species and/or groups of species of public interest change. There is a vast difference in what the publics in Oregon and California consider important. To some vocal publics, wildlife means production of harvestable species, while to others it means animals for viewing, while for yet others it means just knowing that it exists.

Emphasis in land management agencies seems to be shifting towards species richness management. The management systems that provide habitat for harvestable and non-harvestable species are the same, but utilized with different emphasis.

In terms of public land management, Federal agencies are usually considered re-responsible for providing habitat, while State agencies manage the animals. On paper this relationship works well. On-the-ground, it is not that easily accomplished. Cooperative interagency development of management systems is required if they are to succeed.

MANAGEMENT FOR SPECIES RICHNESS

The goal of management for species richness is to insure that most if not all wildlife species are maintained in viable numbers of a particular area (Evans 1974).

The key to planning the management of all species is to provide a variety of habitat components (which must be described) in a desirable combination and arrangement that will provide individual habitat needs of all species in terms of both time and space. A management program based totally upon the principle of diversity would not intentionally favor one species at the expense of another. The management goal is not animal numbers, but rather specific acres of quality habitat that would support a variety of species of differing densities. The goal would be derived dependent upon the inherent capability of the area to be managed. Sizes of the management areas should be related to the territorial home range requirement of the most demanding of species for which management is intended.

Management for species richness does not provide a strict recipe for land management. Rather, it guides purposeful vegetation manipulation to provide specific habitat conditions or components through time and space on a sustained basis. The same component need not be provided indefinitely on the same acre. The key is to maintain management options while working to meet future goals.

Such management depends upon indentifiable, quantifiable habitat component descriptions such as successional stages or conditions within plant communities. It also recognizes that habitat goals can probably be met only through coordination with the range and timber resource. The value of habitat improvement is addressed. Unique habitats (natural and man-made) that contribute to greater habitat diversity are identified and management recommendations developed.

Well designed guides for species richness management should be flexible and, at the same time protect the integrity, stability, and diversity of the biotic community.

FEATURED SPECIES MANAGEMENT

The featured species concept is the principle of selecting particular wildlife species and concentrating management efforts toward fulfillment of their needs (USDA Forest Service 1971). The purpose is to guide wildlife management including coordination, multiple use planning, direct habitat improvements and cooperative programs. The purposes may be as diverse as to insure the welfare of endangered species, provide songbirds around campgrounds, insure harvestable surpluses of game species, or increase insect-eating birds to help hold insects at endemic levels.

Habitat surveys are used to determine potential for candidate species. Selection is based upon habitat capability, compatibility with other resources, laws, public interest, needs and involvement.

Featured species management plans identify habitat requirements and define habitat components of selected species. These must be listed specifically and in terms recognizable by land managers. Population or habitat goals or both are established. Management direction is then formulated to achieve the selected goals.

Under this concept, 12.3 million acres of National Forest land in 14 Southern States are manipulated and controlled to provide predictable food and cover conditions to meet recognized habitat requirements. The concept is a positive approach to wildlife habitat management.

SUMMARY

An understanding of the basic ecologic laws and principles and wildlife management concepts are essential to the habitat manager. These are quite often not known, understood, or utilized - particularly in application to actual management. On most public land today habitat manipulation results primarily from actions undertaken to produce wood fiber, red meat, or some other commodity. These activities must be guided and modified to provide specific wildlife habitat goals as well. It is only through well coordinated management that several predictable resource outputs can be simultaneously achieved.

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SILVICULTURAL OPTIONS AND HABITAT VALUES IN CONIFEROUS FORESTS[1]

Paul J. Edgerton,[2] and Jack Ward Thomas[3]

Abstract.--The welfare of all birds must be accounted for in forest management decisions. Different bird species select different forest types and successional stages for feeding and reproduction. Birds are grouped into life forms according to habitat requirements. Using this framework, a system for evaluating bird response to habitat alteration due to silvicultural systems and associated practices is presented.

TIMBER MANAGEMENT AND BIRDS

Timber management is the dominant land management activity in Pacific Northwest forests. Harvest and regeneration methods significantly alter the forest environment. Resulting changes in wildlife habitats are immediate, dramatic, and relatively long-lasting. Although some attention has been given to conflicts with fisheries and big game, consequences to forest birds have been largely unknown and unplanned by land managers. Large-scale wildlife management has generally been an afterthought, a potluck affair with timber management objectives dictating the choice and quality of habitats available to wildlife.

Traditionally, land management agencies have assigned biologists the task of monitoring game animals and their habitats and preventing or alleviating wildlife damage to young forest trees. Only recently have legal and professional responsibilities to manage both game and non-game wildlife and their habitats been recognized. Initial efforts have centered around the protection of unlogged habitats on which several species are absolutely dependent. The interest shown in this workshop and in regional efforts to develop comprehensive timber-wildlife coordination guidelines is further evidence of a recognition by land managers that timber management is wildlife management as well. Meaningful management programs for forest birds require that animal needs and habitat response are given consideration in both the formulation and the implementation of land management decisions.

The purpose of this paper is to provide a conceptual framework for predicting the generalized response of plant communities and forest birds to environmental changes resulting from implementation of an array of silvicultural systems and associated forest practices. Examples are drawn from a comprehensive compilation of information pertaining to wildlife species occurring in the Blue Mountains of northeastern Oregon (Thomas et al.[4]). Although forest types, successional communities, and bird species may vary considerably from area to area, the concept should be applicable.

FOREST STRUCTURE AND HABITAT SELECTION

There is much evidence indicating that habitat selection by many forest birds is primarily related to general features of terrain and vegetation. Structure of vegetation is particularly important. Birds respond more often to canopy characteristics such as height, profile, volume, and density than to plant composition (Balda 1975, MacArthur 1964, MacArthur et al. 1962, Odum 1945, Pitelka 1941, and many others).

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[4] Thomas, J. W. et al. 1976. The relationship of terrestrial vertebrates to plant communities and their successional stages. Unpublished report. U.S. Dep. Agric. For. Serv., Pac. Northwest For. and Range Exp. Stn., La Grande, Oregon.

Structural differences between plant communities within a forest type reflect the advancement or retrogression of the development of a forest over a period of time. Although each community is dynamic and everchanging, it has distinct structure more or less characteristic of a particular successional stage. Of special importance to wildlife biologists and land managers is that successional stages are recognizable and generally predictable and that individual stages or combinations of stages provide niches that attract bird species with various unique habitat requirements for feeding and nesting.

Forest management practices, especially silvicultural practices, alter the direction and pace of forest succession. Depending on the practice and the management objective, successional stages may be accelerated, shortened or even bypassed. Nevertheless, treated (managed) stands structurally resemble natural successional stages, and we think they generally attract the same kinds and numbers of birds as do similarly structured natural stands. This relationship is the basis for the predictive information being developed for use by biologists and land managers in the Blue Mountains. 4/

Meslow (this workshop) has explored successional relationships in greater depth with emphasis on forests west of the Cascade Range in Oregon and Washington. To develop our topic, it is necessary to review bird response to successional stages using the Blue Mountains of Oregon and Washington as an example.

Communities, Successional Stages and Structure

Forest types in the Blue Mountains with significant commercial timber value include ponderosa pine, mixed conifer, white fir (grand fir), subalpine fir and lodgepole pine. Typically, these forests evolve through generalized successional stages we categorize as: grass-forb → shrub-seedling (0-10 years) → pole-sapling (11-40) → young forest (41-100) → mature forest (101-200) → old growth (201+). Ages shown are approximate and can be markedly influenced by timber type, management practices, and site factors. Relative environmental characteristics of successional stages are evaluated in table 1.

Table 1.--Generalized forest successional stages and relative environmental characteristics.1/

Condition	Successional stages					
	Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
Canopy closure		XX	XXXX	[illegible]	[illegible]	[illegible]
Herbage production	XXXXX	XXX	XX	X	XX	[illegible]
Shrub production	X	XXXXX	XX	X	XX	[illegible]
Canopy volume		X	XX	XXX	XXXXX	XXXX
Plant diversity	XXXX	XXXXX	XXX	X	[illegible]	XXXXX
Structural diversity	X	XXX	XX	X	[illegible]	XXXXX
Animal diversity	XXX	XXXX	X	XX	[illegible]	XXXX

1/ The number of X's indicates relative magnitude.

These are the elements of structure and as such are useful for interpreting and predicting species response to changes in forest stands.

Bird Response

Biologists recognize that bird species differ in their ability to adapt to habitat alteration. Some species are quite adaptable to changes in vegetation structure and composition. Other species are dependent on specific habitats and may require greater management consideration. As a first step towards organizing published and unpublished knowledge of forest birds into a useful format, individual species response or orientation for feeding and reproduction have been tabulated for each forest type and successional stage. Table 2 displays this information for species occurring in the ponderosa pine forest type.

Table 2--Bird species orientation to generalized forest successional stages in the ponderosa pine forest type, Blue Mountains, Oregon[1]

Life form number	Species	Forest successional stage					
		Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
3	Dipper	X 0	X 0	X 0	X 0	X 0	X 0
4	Turkey vulture	X 0	X 0				X 0
4	Ferruginous hawk	0					
4	Peregrine falcon	0	0	0	0	0	0
4	Black swift	X 0	0				
4	White-throated swift	X 0	0				
4	Say's phoebe	X 0	X 0	X 0	X 0	X 0	X 0
4	Common raven	X 0	X 0				X 0
4	Canon wren	X 0	X 0				
4	Rock wren	X 0	X 0				
5	Blue grouse	0	X 0	X 0	0	0	0
5	Ruffed grouse		X 0	X	0	X 0	X 0
5	Mountain quail	0	X 0	X 0	X 0	0	0
5	Turkey	0	X 0	X	X	0	0
5	Hermit thrush			0	0	0	0
5	Dark-eyed junco	X 0	X 0	X 0	X 0	X 0	X 0
6	Common nighthawk	X 0	X 0	0	0	X 0	X 0
6	Townsend's solitaire	0	0	0	0	0	0
7	Solitary sandpiper	0	0	0			
7	Calliope hummingbird	0	0	0	0	0	0
7	Gray flycatcher	0	0	0	0	0	0
7	Black-billed magpie	0	X 0	X 0	X 0	X 0	X 0
7	Piñon jay		0	0	0	0	0
7	American robin	0	X 0	X 0	X 0	X 0	X 0

Life form number	Species	Forest successional stage					
		Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
7	Loggerhead shrike	0	0	0	0	0	0
7	Brewer's blackbird	0	X 0	X 0	X 0	X 0	X 0
7	Brownheaded cowbird	0	X 0	X 0	X 0	X 0	0
7	Green-tailed towhee	0	0	0	0	0	0
7	Chipping sparrow	0	X 0	X 0	X 0	X 0	X 0
8	Dusky flycatcher	0	0	0	0	0	0
8	Bush-tit		0	0	0	0	0
9	Northern oriole		0	0	0	0	
9	House finch	0	0	0	0	0	0
10	Olive-sided flycatcher	0	0	X 0	X	X 0	X 0
10	Clark's nutcracker				0	0	0
10	Golden-crowned kinglet		0	0	0	0	0
10	Ruby-crowned kinglet			0	0	0	0
10	Yellow-rumped warbler			0	0	0	0
10	Townsend's warbler				0	0	0
10	Western tanager		0	0	X 0	X 0	X 0
10	Red crossbill				0	X 0	X 0
11	Goshawk		0		0	0	0
11	Sharp-shinned hawk		0	0	0	0	0
11	Cooper's hawk	0	0	0	X 0	X 0	0
11	Merlin	0	0	0	0	X 0	X 0
11	Long-eared owl	0	0	0	0	0	0

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[1] "X" denotes reproduction, "0" denotes feeding.

(Continued p. 59)

Table 2--Bird species orientation to generalized forest successional stages in the ponderosa pine forest type, Blue Mountains, Oregon--Continued

Life form number	Species	Forest successional stage					
		Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
11	Hammond's flycatcher		O	O	O	X O	X O
11	Western wood peewee		O	O	X O	X O	X O
11	Steller's jay	O	O	X O	X O	X O	X O
11	Common crow	O	O	O	O	O	O
11	Solitary vireo			O	O	O	O
11	Red-eyed vireo			O	O	O	O
11	Warbling vireo		O	O	O	O	O
11	Black-headed grosbeak	O		O	O	X O	X O
11	Evening grosbeak	O		O	O	X O	X O
11	Purple finch	[illegible]	O	X O	X O	X O	X O
11	Cassin's finch	O	O	O	X O	X O	X O
11	Pine grosbeak			O	O	X O	X O
11	Pine siskin	O	O	X O	X O	X O	X O
[illegible]	Red-tailed hawk	[illegible]	[illegible]	[illegible]	O	X O	X O
12	Golden eagle	X O	X O	O	O	X O	X O
[illegible]	Bald eagle	[illegible]	[illegible]			X O	X O
[illegible]	Osprey					[illegible]	[illegible]
[illegible]	Great horned owl	[illegible]	X O	X O	X O	X O	X O
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X [illegible]	X O	[illegible]
[illegible]	[illegible]					[illegible]	[illegible]
[illegible]	Lewis' woodpecker	[illegible]	[illegible]		X O	X [illegible]	X [illegible]
[illegible]	[illegible]				[illegible]	[illegible]	[illegible]
[illegible]	[illegible]					[illegible]	[illegible]

Life form number	Species	Forest successional stage					
		Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
13	Hairy woodpecker				X O	X O	X O
13	White-headed woodpecker					X O	X O
13	White-breasted nuthatch					X O	X O
13	Pygmy nuthatch					X O	X O
14	Common merganser					[illegible]	[illegible]
14	American kestrel	O	O		X	X	X O
14	Barn owl	O	O			[illegible]	[illegible]
14	Flammulated owl	O	O		[illegible]	[illegible]	[illegible]
14	Pygmy owl	O	O	O	[illegible]	[illegible]	[illegible]
14	Barred owl	O	O			[illegible]	[illegible]
14	Saw-whet owl				[illegible]	[illegible]	[illegible]
14	Ash-throated flycatcher	O	O			[illegible]	[illegible]
14	Violet-green swallow	O			[illegible]	[illegible]	X
14	Tree swallow	O	O		X	[illegible]	X O
14	Mountain chickadee				X O	X O	X O
14	Brown creeper				O	X O	X O
14	House wren	O	O			X	[illegible]
14	Western bluebird	O	O		[illegible]	X	[illegible]
14	Mountain bluebird	O	O		X	[illegible]	[illegible]

See footnote at end of table, p. [illegible].

Life Forms

Further, species have been grouped into 16 life forms according to similar habitat requirements for feeding and reproduction (Table 3).

Table 3--Description of vertebrate life forms occurring in the Blue Mountains, Oregon.

Life form number	Reproduces	Feeds
1	in water	in water
2	in water	on ground, in bushes and/or trees
3	on ground around water	in water, on ground, in bushes and trees
4	in cliffs, caves, rims, and/or talus	on ground or in air
5	on ground without specific water, cliff, rim, or talus association	on ground
6	on ground	in bushes, trees, or air
7	in bushes	on ground, in water or air
8	in bushes	in bushes, trees, or air
9	primarily in deciduous trees	in bushes, trees, or air
10	primarily in conifers	in bushes, trees, or air
11	in trees	on ground, in bushes, trees, or air
12	on very thick branches	on ground or in water
13	excavates own hole in a tree	on ground, in bushes, trees, or air
14	in a hole made by another species or naturally occurring	on ground, in water, or air
15	underground burrow	on or under ground
16	underground burrow	in water or air

For example, the western bluebird has been included in life form 14 with other vertebrates that reproduce in holes excavated by other species and that feed in the air, in water, or on the ground. This concept was adapted from Haapanen's (1965) division of the birds of the Finnish forest. We should emphasize that life form responses to plant community and successional stage or condition are generalized and individual responses can be expected to vary somewhat according to specific habitat requirements. Nevertheless, most species of a particular life form will react similarly to most land management practices. This approach promises to be acceptable and useful to land managers because it greatly reduces the number of species that must be accounted for in generalized land-use planning.

Diversity Related to Successional Stage

Comparison of the habitat value of forest types and successional stages is facilitated by summarizing orientation information as shown in figures 1 and 2.

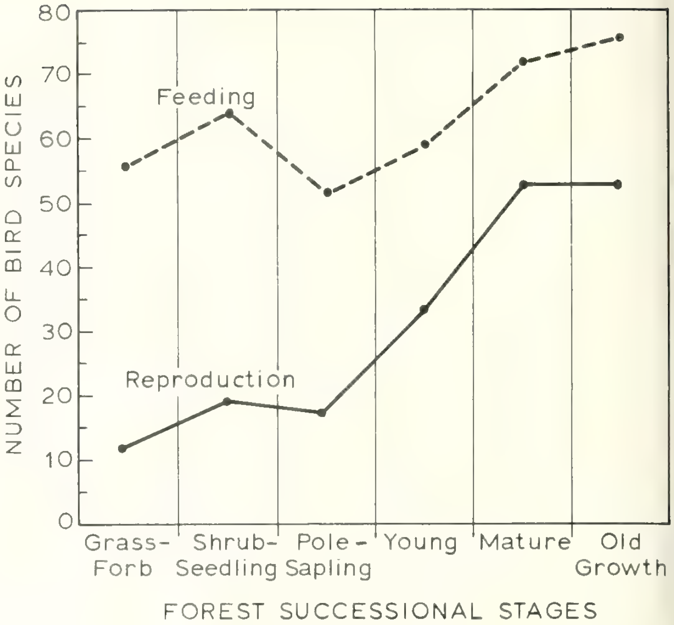

Figure 1.--Bird species orientation to generalized forest successional stages in the ponderosa pine forest type, Blue Mountains, Oregon.

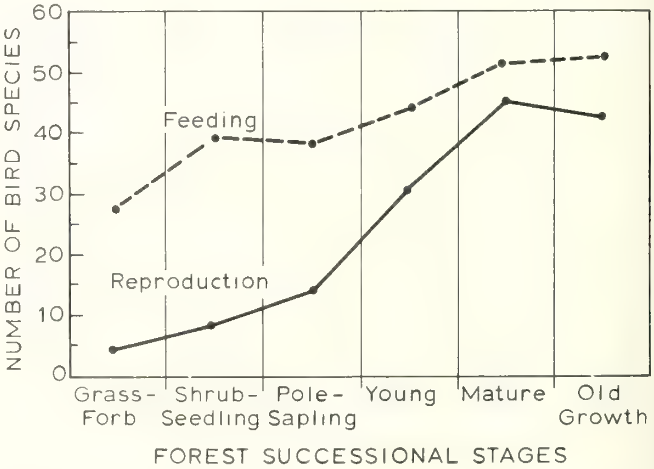

Figure 2.--Bird species orientation to generalized forest successional stages in the white-fir forest type, Blue Mountains, Oregon.

These examples graphically illustrate the concept that species diversity increases as forest succession advances toward maturity (Johnston and Odum 1956, Weins 1975). A majority of the species inhabiting these types both feed and nest in the mature and old-growth successional stages. Comparison of types further shows that ponderosa pine forest provides habitats for more kinds of birds. We speculate this is due not only to greater inherent structural diversity but also an altitudinal or climatic effect as suggested by Wiens and Nussbaum (1975). Ponderosa pine forests generally occur at lower elevations and on southerly exposures. The growing season and snow-free period are much longer than in the white fir forest type found at higher elevations and on north-facing slopes. Many species find the ponderosa pine forest a more favorable habitat during the spring and early summer periods. Certainly, the microclimate is more conducive to early nesting species, particularly ground nesters such as blue grouse. Some of these same species feed in higher elevation forests later during the summer and fall.

It is also revealing to examine life form orientation as presented in figures 3 and 4.

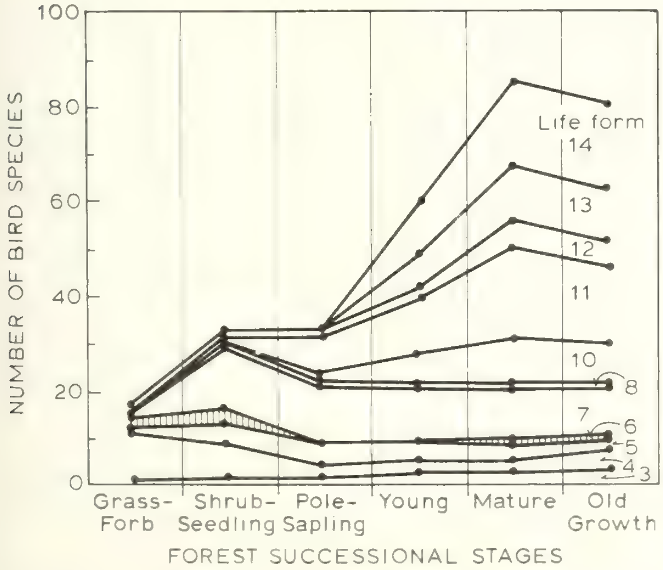

Figure 3.--Bird species reproducing in generalized forest successional stages in commercial forest types, Blue Mountains, Oregon. Number of species by life forms are shown as proportions of the cumulative total. Species of life form 6 reproduce only in those stages indicated by "hatched" lines.

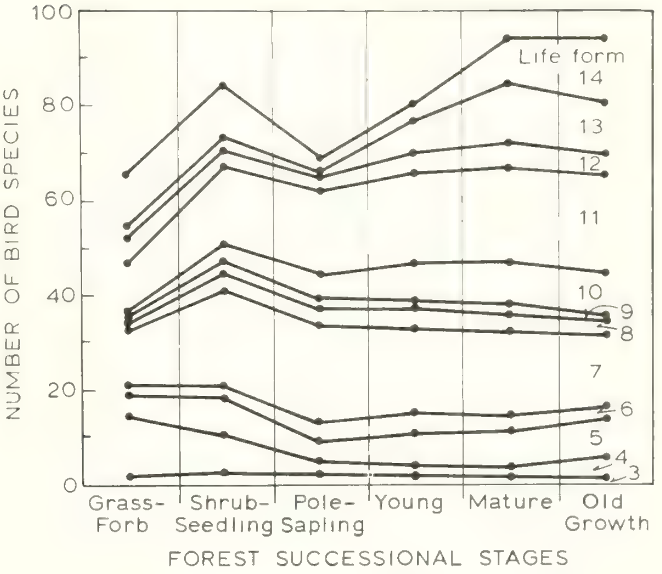

Figure 4.--Bird species feeding in generalized forest successional stages in commercial forest types, Blue Mountains, Oregon. Number of species by life forms are shown as proportions of the cumulative total.

Life form 7 includes several species that are found feeding and nesting in several successional communities. It is likely that these species are quite adaptable to habitat alteration. On the other hand, some of the cavity nesters of life form 13 and 14 also search for food in younger successional stages but are absolutely dependent on the presence of nearby mature or old-growth stands for reproductive habitat (reviews by Curtis and Ripley 1975 and Jackman 1974). Species in life form 6 which nest on the ground and in bushes, trees, or the air do not nest in pole-sapling or young forests. We suspect that lack of understory vegetation (see table 1) to conceal and/or shelter nesting birds from predation and weather is a significant factor discouraging use of these communities.

Habitat Condition as a Predictive Tool

As a result of the display and discussion of what is known about birds in the Blue Mountains, we hope it is apparent that sufficient information is at hand to predict, at least roughly, which particular successional stages or combination of stages best provide the habitat requirements for each life form of birds. Coupled with an understanding of how silvicultural practices advance or retard the successional appearance or structure of forest communities, this knowledge allows us to evaluate, plan for potential benefit, or prevent harm to individual species or bird populations as a result of land management decisions.

SILVICULTURAL OPTIONS AND BIRD RESPONSE

Silvicultural Definitions

Silviculture has been defined as: (1) the art of producing and tending a forest, (2) the application of the knowledge of silvics in forest culture, and (3) the theory and practice of controlling forest establishment, composition, and growth (Smith 1962). In essence, silvicultural practices can be used to mold the forest in desired directions, forms, or conditions. Economical wood production is commonly the primary objective; but consideration of other resource values is encouraged or required, particularly on public lands. Silvicultural practices can also be used for improving forage for wildlife and livestock, maintaining esthetic beauty of forests used for recreation, and increasing water yields from forested watersheds. Silviculture is the basis for intensive forest management often popularly referred to as "high yield" forestry.

Silvicultural Practice and Habitat Diversity

Until recently, silvicultural practices used to harvest and regenerate existing forests were generally thought to benefit habitat diversity for wildlife. As management has intensified and been applied to increasingly larger areas of forest land, it has become apparent that a decline in the diversity of plant communities and animal populations may result. Thomas et al. (1975) have explained this change as being subject to the principle of diminishing returns: "each (silvicultural) practice will yield initial large returns in terms of diversity, but each increment will add proportionately less until finally the increments begin to cause losses in diversity." They attributed the loss of diversity of bird habitats in intensively managed forests to: (1) truncated succession, (2) elimination of old-growth habitats, and (3) removal of snags and standing dead trees.

In their discussion of succession in Douglas-fir forests, Meslow and Wight (1975) added a fourth factor, the development of monocultures. These factors are interrelated; our discussion will focus primarily on the importance of truncated succession and the contribution of individual practices to its development.

Truncated Succession

Emphasis on wood production as the goal of timber management frequently dictates the selection of practices that favor the establishment of the most economically valuable tree species, emphasize rapid growth, and shorten the time until harvest. Ecologically, the result is a truncated successional pattern in which both early and late stages have been shortened or eliminated. In the grass-forb and shrub-seedling stages, practices are applied to encourage tree growth and hence shorten the time in these stages. Practices may include reduction of competing vegetation, tree planting, thinning, and fertilization. In the advanced stages, trends towards utilization of smaller logs and management for shorter rotation age assure earlier harvest of mature stands and elimination of unreserved old-growth forests in order to replace senescent stands with vigorous, faster growing, and more economically efficient stands.

The potential impact of the loss of these habitats on birds occurring in Blue Mountain forests is shown in figure 5.

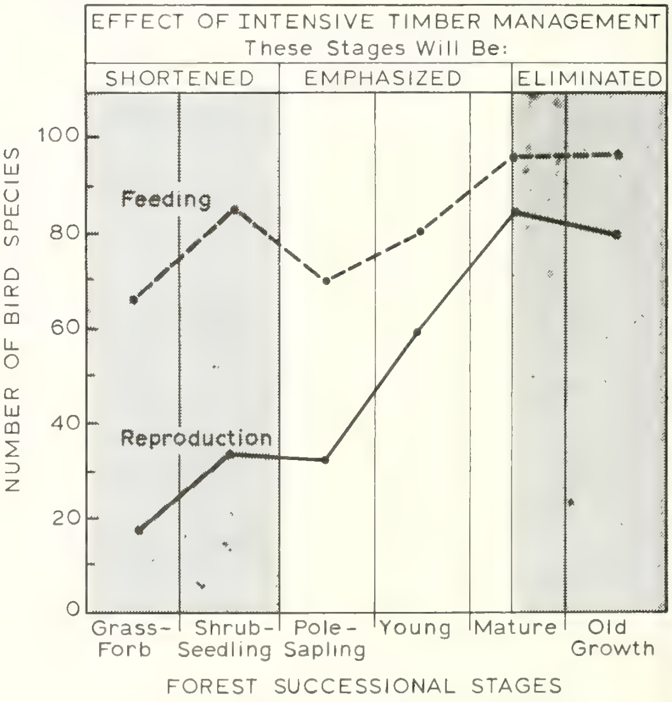

Figure 5.--Bird species oriented to generalized forest successional stages in the Blue Mountains and the potential effect of intensive timber management on those stages.

The effects of "streamlining" the early stages is not of great concern at this time. Although many birds utilize these stages, it is doubtful that with present harvest schedules and funding enough treatment of understory vegetation will be accomplished to an extreme that will jeopardize these habitats. Elimination of mature and old-growth forests is, potentially, a more serious problem. These multi-storied habitats provide niches for feeding and nesting for many species, several of which are presently considered extremely specialized and well adapted only to those environments (Wight 1974). Those stages (pole-sapling and young forest) emphasized by intensive management lack several qualities of structural diversity found in the affected stages (see table 1). The related decrease in bird diversity in these mid-successional stages agrees with the results of studies elsewhere by Johnston and Odum (1956), Haapanen (1965), and Meslow and Wight (1975). MacArthur and MacArthur (1961) also associated this with a reduction in the complexity of vegetative structure.

SILVICULTURAL SYSTEMS

The Selection of Silvicultural Options

Forest managers have a choice of several basic silvicultural systems for harvesting and regenerating forest stands. Selection of a particular system is based on specific management objectives, stand conditions, and a knowledge of how the environment will affect the growth and development of tree species present or desired. Each system has a different potential effect on the diversity and stability of the forest ecosystem. Thus, it is important that biologists as well as forest managers have basic understanding of these systems in order to predict the consequences of their application on forest birds and their habitats. The following discussion of silvicultural systems has been condensed from USDA Agricultural Handbook No. 445.

Selection Systems or All-Aged Management

The *selection system* removes mature and immature trees singly or in groups at intervals. Regeneration is established almost continuously. An uneven-aged stand is maintained with trees of different ages or sizes intermingled singly or in groups. The two types of selection are as uniform or individual trees and groups.

Individual (single) tree selection removes individual trees rather than groups of trees. In mixed stands it leads to an increase in the proportion of shade-tolerant tree species.

Group selection maintains a higher proportion of the less shade-tolerant species in a mixture. Group size varies according to characteristics of the site, the stand, and the species to be favored but may be as large as an acre or two. Large groups resemble small clearcut patches, but the system is distinguished from clearcutting in that its intent is creation of a balance of age or size classes in intimate mixture or in a mosaic of small contiguous groups throughout the forest.

Even-Aged Management

The remaining systems--shelterwood, seed-tree, and clearcutting--result in stands of trees of about the same age.

The *shelterwood system* removes the mature stand in a series of cuts. The new stand is established under the cover of a partial canopy. A final harvest cut removes the shelterwood and permits the new stand to develop in the open as an even-aged stand. This system provides a continuing tree cover and is especially adapted to species or sites where shelter is needed for the new reproduction or where inhibition of competing vegetation is desired.

The *seed-tree* system harvests nearly all the timber in a selected area in one cut. A few of the better trees of the desired species are left well distributed over the area to reseed the site naturally.

Clearcutting harvests, in one cut, all trees on an area to create a new, even-aged stand. The area harvested may be a patch, stand, or strip. Regeneration is obtained through natural seeding, planting, or direct seeding. The absence of reserve trees facilitates slash disposal, site preparation, and other cultural treatments.

Phares (1976) stated that:

> *...stands of irregular structure and tolerant species are best suited to uneven-aged management. Fragile sites, steep slopes, high water tables, and very dry sites that would be adversely affected by complete removal of forest cover are better suited to uneven-aged silviculture is most effective in even-aged stands of intolerant species and it should be used to return overmature, decadent, diseased or insect infested stands to productivity.*

Habitat Response to Silvicultural Systems

Uneven-aged management tends, over time, to produce a continuous forest cover dominated by relatively mature trees. Vertical diversity is enhanced while horizontal diversity decreases. The forest lacks a variety of distinct successional stages that provide habitat required by many kinds of birds. Openings due to group selection of trees develop, over time, a greater diversity of vegetation structure than does single tree selection. The territorial requirements of many bird species favored by early succession may, however, exceed the size of opening available. Size of the area is the key to use (Gill et al. 1976). This is discussed further by Thomas et al. (this workshop).

Even-aged management gives land managers and biologists greater flexibility to produce stands of appropriate size and structural diversity to meet the varied needs of forest wildlife, including birds. Size and shape of harvest units determine horizontal diversity and the amount of edge (Thomas et al., this workshop). Distribution in time (age) and space (location) determine the available array of successional stages and edges. Lack of vertical diversity within even-aged stands must be offset by the maintenance of maximum structural diversity among stands within a management area.

IMPACT OF VEGETATIVE MANIPULATION

Selection of the basic silvicultural system, e.g., selection, shelterwood, clearcutting, etc., establishes the general pattern of succession and bird response. As discussed earlier, however, additional silvicultural treatments will be used to "streamline" the development of the stand. They will favor some birds and eliminate habitat for others. Some anticipated changes in forest community structure are shown in table 4.

Table 4--Anticipated changes[1/] in structural appearance of forest communities due to application of selected management treatments.

Treatment	Successional stage					
	Grass-forb	Shrub-seedling	Pole-sapling	Young	Mature	Old growth
Silvicultural system:						
Individual selection				→	→	--
Group selection				←	→	--
Shelterwood				→	←	←
Seed-tree				←	←	←
Clearcutting				←	←	←
Thinning		→	→	→	→	--
Salvage			←	←	←	←
Reduction of understory						
Competition:						
Herbicides	→	→	→	←	←	←
Mechanical	←	←	-	←	←	←
Prescribed burning:						
Cold burn	→	→	→	→	←	←
Hot burn	←	←	←	←	←	←
Fertilization	--	→	→	→	→	--
Planting:						
Trees	→	→				
Grasses and forbs	--	←	←	→	→	--
Grazing-browsing:						
Proper use	→	→	→	→	←	←
Excessive use	←	→	→	←	←	←

[1/] → advances succession, ← sets back succession, -- no effect on succession

By changing the structural appearance of the stand, the treatments listed can be considered as either advancing or setting back succession. For example, use of herbicides causes the early successional stages to appear older; a hot prescribed burn sets succession back.

There is bound to be disagreement over the direction of some of the responses. This is expected because the great variety of plant communities with which land managers are concerned will not all respond in the same generalized fashion. The point we emphasize is that in planning the harvest and management of forests, biologists and managers assemble the kinds of information we have presented so that they can reasonably predict habitat changes and their effects on the kinds and numbers of birds.

SUMMARY

The role of biologists has increased to include the responsibility to account for impacts of land management practices on all birds. Given present and foreseeable levels of funding and staffing and the massive anticipated amounts of activity involving manipulation of forest vegetation, it is probably impossible to maintain a position of dealing with individual species.

It seems probable that habitats can be accounted for more easily and accurately. Habitats have particular characteristics; and these are the key to predicting, albeit crudely, the bird component of that community in that stage. We feel that we have the knowledge to make such predictions about most species now. Further, this ability can be refined much more rapidly by additional research than the traditional species-by-species approach.

Habitats to a biologist are stand conditions to a forester. As such, we have a common key to cooperation and the ability to consider habitats and, in turn, birds as products of silvicultural systems and treatments.

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RANGELAND MANAGEMENT PRACTICES AND BIRD HABITAT VALUES [1]

Robert R. Kindschy [2]

Abstract.--Modification of the vegetation of the rangelands of Western North America, with particular emphasis on the sagebrush/bunchgrass community is discussed. Implications upon the avifauna are explored with management suggestions for the future creation of more diversified ecosystems.

INTRODUCTION

Rangeland vegetation includes shrub lands, grass lands, and open forests where dry sandy saline or wet soils, steep topography, or other inhibiting factors preclude the growing of commercial farm or timber crops. Rangeland occupies approximately 47% of the earth's land surface; farming, 10% commercial forests, 28%; and ice covers 15% (Williams et al. 1968).

The avifauna of the world depends to a great extent on the desert and rangelands to support it during the winter period. A differentiation between game and nongame birds is invalid when the concepts of ecology are examined. The same rules that apply to the much studied game bird species apply to the so called nongame species, and much of what has been learned through years of research with these more popular species can be applied equally well to the nongame species.

Buttery and Shields (1975) summarized the impacts of livestock grazing and range modifications for livestock grazing quite adequately in a similar paper presented in Tucson. In this paper I attempt to broaden the concept presented by Buttery and Shields and expand it to range impacts other than livestock grazing and range vegetation manipulation for livestock grazing.

Of foremost concern is the realization that bird populations respond to habitat changes. Certain bird species favor brushland type habitats whereas others are prone toward grassland type habitats. The general goal of range management is toward the "improvement" of range conditions through advancement of the successional stage of vegetation toward climax. The western ranges of North America have undergone over 100 years of grazing by domestic livestock preceeded by countless centuries of grazing by large herbivores which effectively converted the vegetation to successional stages some considerable extent less than climax.

Modification of existing vegetation must be attempted with the caution that habitats will be altered and the resultant avifauna will similarly respond to the change in habitat. Much of the western range is dominated by stands of brush species. Sturges (1973) estimated that 58.3 million hectares of range in North America were populated by stands of big sagebrush, Artemisia tridentata. Schneegas (1967) estimated that 2.0 to 2.4 million hectares of sagebrush had been treated by some method. It has further been conservatively estimated that 10% of the sagebrush rangelands in the western portion of North America have been altered to some degree in the past several decades; conversely, 90% of the sage lands of the western portion of the continent have not been altered by vegetative manipulation. This particular ecosystem is especially abundant and forms a monotonous monocultural over vast areas of the cold desert biome.

A rich variety of bird fauna is obtainable through a correspondingly rich variety of habitat; in short, habitat diversity of cover, food, and water is the key to a wide variety of bird species in the western rangelands.

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[1] Presented at the workshop on Nongame Bird Habitat Management in Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

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The March 1976 issue of the Wilson Bulletin contained a paper entitled "Conservation Committee Report on Effects of Alteration of Sagebrush Communities on the Associated Avifauna" (Braun 1976). This is an extremely good resume of the history of the sagebrush biome in the western portion of North America which discusses impact of some of the alterations caused by livestock grazing and the artificial manipulation of the resultant vegetation. The principle effect of unregulated livestock grazing upon sagebrush/bunchgrass rangelands has been an increase in the density of sagebrush. It is believed by many that wildfires controlled the density and occurrence of big sagebrush and other related species in the pristine Artemisia community. The removal of fuel inhibited the fires to the extent that the sagebrush and other non-fire tolerant species were able to perpetuate and increase the density of their stand, thus increasing the amount of habitat available for certain bird species while lessening it for other species.

Birds which are obligates (almost entirely dependent) of the sagebrush community include sage grouse, sage thrasher, sage sparrow, and the Brewer's sparrow. Conversely, species such as the western meadowlark, the horned lark, vesper sparrow, lark sparrow, and mourning doves normally increase when dense stands of sagebrush are reduced and replaced with open areas of grass land. Braun mentions the adverse effect of sagebrush control on raptorial birds; it has been my experience in southeastern Oregon that the increase in rodents, especially ground squirrels, has increased the use of certain rangelands by raptorial birds. The actual increase in numbers of the individuals is not documented, however, and may be a displacement from less desirable ranges.

LIVESTOCK GRAZING

The grazing of livestock on western rangelands has been popular for the past 100 to 120 years throughout much of the western portion of North America. One of the principle effects of livestock grazing has been a conversion of the native vegetation to species of plants which are less palatable to the grazing livestock, notably brush species and certain forbs. While this alteration of the vegetation has benefited certain bird species, it has been detrimental to others. One of the paramount problems has been the elimination of habitat diversity, especially in the riparian vegetational communities, to a rather homogenious vegetational community with its resultant lack of avifaunal variety.

In certain instances the mechanical injury from livestock grazing, especially that of sheep, has been detrimental to ground nesting birds such as the sage grouse and the long billed curlew which may suffer nest breakage and disruption through the impact of the hoofs of these animals,(Sugden, 1933). Buttery and Shields (1975) recognized several livestock grazing systems and speculated on their impact upon the avifauna. I am in basic agreement with their discussions on yearlong grazing, continuous grazing, deferred grazing, deferred rotation and rest rotation grazing, and common use grazing. They did not discuss, however, the alternative of no grazing. The removal of livestock grazing from certain productive habitats, especially the riparian community along streams, along reservoirs and natural occurring lakes and marshes, can create a fantastic amount of additional habitat diversity. These habitat areas are of principle importance for 62% of the bird species identified as occuring within southeastern Oregon rangelands. This same riparian habitat is of great importance for a number of other wildlife species and for domestic livestock. Consequently, the impact of livestock upon this ecosystem is extreme and often completely disruptive.

The initiation of no grazing as a grazing system is valid in creating habitat diversity. While it is true that occasional grazing on a prescription type basis to achieve or maintain a certain vegetative sub climax or climax within the ecosystem is desirable, grazing should be used as a tool only to achieve that vegetative type.

RANGE IMPROVEMENTS

Buttery and Shields (1975) defined a range improvement as any structure, excavation, or treatment to facilitate management of range or livestock.

Water Developments

In most of the cold desert biome, the infrequent occurence of water is the principle lack within the habitat. The development of additional water generally increases the habitat for wildlife species which are dependent upon water. Access to the water by domestic livestock frequently results in a completely denuded vegetative cover and lack of forage. Water that is fenced and controlled to livestock access through the installation of troughs or other facilities which limit the duration that livestock may use the facility helps reduce the negative impact of livestock concentrations on the habitat.

Often throughout the western rangelands, natural occurring springs have been developed through digging and the installation of perforated pipe which collects all of the naturally occurring water and concentrates it in livestock troughs. This development, in effect, eliminates a naturally occurring marsh or bog area and thus removes the forbs and grasses with the associated insect life from these aquatic habitats. A mitigating measure that should be taken at such developments is the piping of overflow water from the troughs onto slopes or flats which are fenced from livestock access thereby recreating a marsh or bog of the same or greater size as was previously present. In some instances it is necessary to artificially re-introduce plant species to these development areas.

Herbicidal Treatment of Vegetation

2,4-D has been widely used to control big sagebrush and related broadleaf species on the western range. The initial effect of 2,4-D application, as analyzed in studies from central Montana by Best (1972), indicate that the initial reduction in sage dependent species of birds, such as the Brewers sparrows, was significant but not complete. Observations in southeastern Oregon indicate that the remaining stand of dead sagebrush often temporarily provides a partial habitat for these species. The principle of habitat structural change seems to be most evident. Initial herbicide application does not change the structure of the habitat in that the brush persists. Gradually the brush will breakdown or will be trampled by livestock, and more prairie-like aspect will occur.

Rangeland Seeding

Tens of thousands of hectares of range were plowed, burned, chained or similarly treated to reduce the overstory of big sagebrush; a portion was then drilled to adapted dryland grass species, generally crested wheatgrass,Agropyron cristatum and A. desertorum. The conversion to a prairie type habitat, which is much more pronounced and extreme in the case of the seeding than in the case of the herbicidal treatment, may be beneficial to certain prairie type species of birds and quite detrimental to species dependent upon the brush. Buttery and Shields state that this practice is largely beneficial to bird habitat because it quickly changes the vegetation from some stage of succession to one more nearly resembling climax, thus providing foodcover better suited to the normal bird species in populations found in an undisturbed ecosystem. It should be pointed out that the more productive successional stages are often quite removed from climax; that climax itself is quite unstable and is constantly fluctuating due to natural occuring causes. Habitat diversity reflecting the variety of successional stages is probably a much more productive and safe concept for overall habitat management.

The vegetative species composition and life form are the principle factors affecting the ecological distribution of birds. Thomas, et al. (1976) stress the importance of the reproductive needs and foraging needs of species. These needs are met to the best extent by the development and maintenance of maximum habitat diversity.

Fire Management

The incidence of large wildfires was greatly inhibited during the past 100-year history of grazing of the western rangelands due to a greatly reduced supply of fuel. With the advent of more intensive range management, there has been an accumulation of fuel through rest rotational grazing and other grazing schemes. Large fires, likely typical of the pristine situation, are more common today. Wildfires typically burn in irregular patterns. This irregularity creates a maximum of "edge effect" and habitat diversity which creates additional diversity of bird species.

Recreation

The impact of humans upon the range ecosystem is of increasing concern to wildlife ecologists. Roads and access trails are allowing year round access to large areas of the uninhabited back country.

The growing popularity of off road vehicle use, including motorcycles and 4-wheel drive and, during the winter, snowmobiles, has created yearlong disturbance of the remote areas of the western range. Distruptions to breeding and nesting are of principle importance. Stress to wintering populations of birds can also be detrimental at a time when food reserves are at a minimum. Human access also favors uncontrolled hunting practices, e.g. "varmint" shooting, which has taken a toll of raptoral species.

Mining and "Rockhounding"

Both recreational and commercial mining of the western rangelands is of growing significance in its relation to disruption of the ecosystem. The impact of both forms of mining is normally severe. The projected increase in energy requirements will require strip mining, coal, uranium, geothermal exploration and development, and oil and gas production - all of which can only have negative effects upon the rangeland ecosystems.

Powerlines and Other Rights-of-Way

Powerlines have both a positive and negative impact upon the avifauna of the desert. High elevation perches are not readily available over much of the western rangeland aspect. The construction of powerlines provided ready perches for eagles, hawks, and other raptors. Unfortunately, the large wing span of these birds caused frequent electrocutions where powerlines were improperly designed. The Idaho Power Company, among others, have assumed the initiative in redesigning its powerlines through the recommendations of Morlan Nelson (1975), world known raptor consultant. Modifications of powerline stringing plus the installation of raptor roosts on key poles have greatly reduced the incidents of raptor electrocution.

RECOMMENDATIONS AND RESEARCH NEEDS

Several of the more pronounced impacts of man's activities to the avifauna of the western rangelands have been identified and discussed. It is apparent that additional knowledge is necessary to evaluate the impacts of proposed actions on a species by species basis. The development of wildlife guidelines along the manner developed by Thomas et al. (1976) for the forests of northeastern Oregon should provide data to predict the impact of habitat change on an ecosystem basis.

Information from the wildlife guidelines format will provide the rangeland manager with information to evaluate the effect of his land use and manipulation decisions upon the rangeland ecosystems. Background data to develop these guidelines is desperately needed. These include:

1. Identification of the bird species, both game and nongame which utilize the rangeland ecosystems.

2. Identify and quantify the habitat requirements of the species in a manner so as to be useful in formulating range management plans.

3. Develop range livestock grazing systems and range improvement practices in a manner so as to create the maximum diversity of habitat types within the rangeland ecosystems.

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GUIDELINES FOR WILDLIFE MANAGEMENT
IN
WESTERN CONIFEROUS FORESTS [1]

Rod Miller [2]

Abstract. -- Lack of specific objectives and guidelines for wildlife habitat on given units of land is suggested as a major problem facing land managers. A process for development of such objectives is discussed, and goals and objectives presently in use on the four National Forests in northeastern Oregon, are displayed.

THE PROBLEM

Few Environmental Analysis reports for timber sales state which wildlife species occur in the sale area, the habitat on which they are dependent, and how that habitat will be maintained, decreased, increased, or supplied elsewhere. In addition, few reports specifically state the amount of the different kinds of important habitats which will be maintained on a designated unit of land.

Many of these same reports will be quite specific as to silvicultural objectives, volume of timber to be removed, or the long-range objectives of the transportation system. Few, however, will speak to the concepts or methods employed to maintain various forms of wildlife habitat. Meanwhile, timber harvest continues and new areas are entered every year without specific wildlife habitat objectives.

Why does this problem exist? There are numerous Federal laws that state, or at least imply, that wildlife or wildlife habitat, the environment, and habitat diversity will be maintained. It seems clear that Congress never intended that the habitat for any existing form of wildlife on Federal lands be significantly decreased. By and large, however, Congress has left the amount and location of wildlife habitat up to the States, and to Land Management Agencies. This places an agency in an extremely responsible position. With public involvement, such decisions as the following must be made:

1. How much and where should optimum habitat for deer or elk be maintained?
2. How much habitat should we maintain for spotted owls or goshawks and where should it be located?
3. Will habitat for the pine marten be located throughout forested areas or limited to Wilderness Areas?
4. Will we maintain habitat for high, medium or low levels of tree-cavity-dependent wildlife?

These are extremely difficult questions to answer. In many cases, biological information has not been readily available. In other cases, there has not been adequate concern by the public or by the responsible agencies. Funding to solve the problem has been largely inadequate; and in nearly all cases, there has been significant economic, social, and political pressures for either more or less wildlife.

I believe that we now have all the resources needed to answer these questions if we are only willing to face them.

The remainder of this paper describes a process that a group of people in northeast Oregon used to develop wildlife habitat goals and objectives. I will also portray what the goals and objectives are and how they can be used.

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[1] Paper presented at the workshop on Nongame Bird Habitat Management in Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

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INTRODUCTION

Several years ago biologists in northeast Oregon were discussing a great multitude of things that were right and wrong with themselves, the Forest Service and the world in general. From this gathering dawned the reality that the best opportunities for wildlife habitat management on National Forest lands was not in individual improvement projects, but with the modification of timber harvest activities in such a manner as to maintain or enhance wildlife habitat. Most people call this "coordination". But how much coordination is adequate? Where and when should it be done and when is it complete? Our problems were just beginning because we knew we were lost without some specific objectives or guidelines.

In other words, we believed that the Forest Service land manager needed some means of specifically measuring his ability to take reasonably good care of wildlife habitat. We wanted to set up an accountability system for wildlife habitat.

It is extremely timely that we deal with this. The Environmental Policy Act of 1969, the Resource Planning Act of 1974, and more recently the National Forest Management Act of 1976 require that we do a responsible job of planning and managing our resources with minimum impacts on the environment. Land use plans are being prepared which allocate large areas of land to various primary uses. In order to do this intelligently, we must have a system of easily displaying to ourselves and to the public the consequences of different levels of management. Only in this manner can enlightened and knowledgeable decisions be made.

DEVELOPMENT

After much floundering on where to start, we decided we needed a definite "goal". After it was completed, we could then go on to the development of specific objectives to attain that goal.

As a minimum, our goal was to do two things:

1. Indicate the maximum size area on which the goal and objectives would be applied.
2. Indicate general levels of all wildlife to be maintained within that maximum sized area.

Why do we need to express approximate population levels of wildlife? The simplest answer is that without these expressed levels, land managers run the risk, through habitat manipulation, of entirely eliminating certain wildlife species while favoring others. In northeastern Oregon we recognized that some species would increase and others would decrease as a result of our land management activities. The one thing, however, we did not want to do was to unknowingly eliminate the habitat for any existing species of wildlife. A goal to maintain optimum or even maximum populations of each wildlife species would not be an attainable goal. On the other hand, even doing nothing on a piece of habitat favors some species over another.

The agreed upon minimum goal was that habitat for all existing species of wildlife would be retained in quantity and quality sufficient to maintain at least self-sustaining populations of each existing species. This indicates the general level of wildlife to be maintained. In essence, this goal says that somewhere in the forests of northeastern Oregon, we would have self-sustaining population levels of all existing wildlife.

Now, let's talk a little about the maximum sized area on which we will maintain at least self-sustaining population levels. In considering this question, we had the following side-boards:

1. Some level of timber harvest and other activities will continue within the forested areas, and most timber sales will cover 1 to 3,000 acres.
2. Good habitat diversity is the basic component of healthy wildlife populations.
3. Relatively large, wildlife gene pools are required.
4. Similar habitats should be close enough for certain species to travel between.
5. Areas should be readily identifiable on the ground.

After much discussion and consideration, we agreed to use the existing Total Resource Inventory Compartments (TRI) as the maximum sized areas. A TRI-compartment is merely a predetermined unit of land for which resource data is stored. In size they average about 5,000 to 6,000 acres. This sized area seemed to best meet the side-boards.

Subsequently, by adding a maximum sized area to the approximate population level, we derived the minimum wildlife habitat goal for the forested areas of northeastern Oregon.

MINIMUM GOAL

The minimum goal was stated as, "On each TRI-compartment on the four Forests, outside of Wilderness or dedicated Roadless Areas, habitat for all existing species of wildlife will be retained in quantity and quality sufficient to maintain at least self-sustaining populations of each existing species."

This goal was not entirely measurable and it had no time constraints, but it told us in general terms where we were headed. The goal also indicated that we couldn't eliminate an existing species within a TRI-compartment of about 6,000 acres. The next step was to develop some specific objectives or constraints to follow in order to attain the overall goal. In this step we recognize that:

1. All wildlife species are dependent on some form of plant or water community or successional stage, or combinations thereof.
2. Some species are also dependent on other habitat components not really considered a plant or water community.
3. There are about 380 different species of wildlife that can be found someplace, sometime on the four-Forest area.

It became obvious that it would be impossible to write objectives for each species of wildlife. We could, however, write objectives that would provide for the different habitats on which the wildlife was dependent.

The first objective we developed dealt with successional stages and plant communities:

Objective No. 1 - "On each TRI-compartment, major commercial and available timber types (mixed conifer, ponderosa pine, lodgepole) would be identified and plans made for at least 5 percent of the total of each major timber type to be distributed in each of five successional stages."

This objective provides for habitat diversity by asking for certain levels of each successional stage of each major plant community within the TRI-compartment. For example, if we had 2,000 acres of mixed conifer plant community within a single compartment, then at any one point in time, at least 100 acres (or 5%) of mixed conifer community should be in each of five different successional stages -- grassforb, shrub-sapling, young sawlog, mature, and old growth.

Except for the "old" successional stage, there should be no significant problem meeting this objective under present concepts of silviculture. It is primarily a matter of timing the different harvest entries in different locations to obtain a variety of successional stages. Maintenance of some old-growth stage will, of course, require special planning and will cause a falldown in maximum timber yield.

This single habitat objective will assure at least self-sustaining populations of the majority of existing wildlife species. There still remained species of wildlife that had some special habitat requirements, so we continued with additional objectives.

Objective No. 2 - "On each TRI-compartment where the mature or old successional stage of a certain timber type comprises 20 acres or less, special plans will be needed to maintain this key habitat."

This objective gives emphasis to special planning for that small, last remaining patch of mature or old successional stage that may be within a compartment.

Objective No. 3 - "Old-growth stands, managed as such, should be at least 20 acres in size and at least 200 feet across with preference toward stands in excess of 100 acres. Within and between adjacent TRI-compartments, the stands should be located on various aspects and slopes and midst a variety of plant communities."

This objective sets some suggested size constraints on plant communities managed in the old-growth successional stage.

These first three objectives give most emphasis on the old successional stage. This was intentional because we believe there are species of wildlife in northeast Oregon that are significantly dependent on this stage (see list below). Also, it is this stage that is most rapidly being lost, particularly at the lower elevations or transitional life zones. Until more information is known on the specific requirements of these species, it appears to be good land stewardship to maintain parcels in such a successional stage.

WILDLIFE SPECIES
SIGNIFICANTLY DEPENDENT
ON
"OLD GROWTH"

Mixed Conifer or Ponderosa Pine
in
Northeastern Oregon

Fisher
Marten
Lynx
Pileated woodpecker
Long-eared bat
White-headed woodpecker
Flying squirrel
Townsend's warbler
Vaux's swift
Silver haired bat
Goshawk

Objective No. 4 deals strictly with habitat for deer and elk.

Objective No. 4 - "Wildlife Habitat Relationships for northeast Oregon will be employed to assure continued big game use at no less than 33% of the 1975 level in each land type in order to meet minimum biological requirements of the animals or continued use of the impacted areas."

Thirty-three percent of 1975 level of use appears to call for a significant reduction in big game populations. Remember, however, our original minimum goal of self-sustaining population levels. Local forest planning or unit land use planning should dictate the actual habitat manipulation and subsequent level of big game use to be maintained on any one forest, planning unit, compartment, or management area. At present, most of such plans in northeastern Oregon call for maintaining habitat for close to the 1975 population levels of deer and elk.

Objective No. 5 - "Wildlife Habitat Relationships for northeastern Oregon will be employed to assure habitat for cavity nesting birds by maintaining the primary excavators at 40% of their maximum potential population on each TRI-compartment."

This objective deals with those species of wildlife that are usually dependent on dead trees. According to "Wildlife Habitat Relationships for northeast Oregon", in a mixed conifer stand the 40% of maximum population level will be met by providing the following numbers of different diameter snags:

- 10" DBH - 30 snags per 100 acres
- 12" DBH - 54 snags per 100 acres
- 20" DBH - 6 snags per 100 acres

Objective No. 6 - "In each TRI-compartment there are certain unique habitats, such as riparian vegetation, cliffs, talus, bogs, or meadows. Special provisions must be made to maintain the intrinsic value of these habitats to provide at least self-sustaining wildlife populations."

This objective calls special attention to certain habitats that are of extreme importance to some species of wildlife. Without some or all of these compartmented habitats, the chance is great that a species will be eliminated within the area.

Objective No. 7 - "Wildlife Habitat Relationships for northeast Oregon" will be employed to assure habitat for the 50% use level of wildlife dependent on down material."

These seven objectives, if favorably considered in land use and activity planning, will provide the habitat to maintain at least self-sustaining population levels. If the objectives are consistently disregarded, existing information indicates that certain wildlife species are likely to be eliminated from significant areas of the forest.

I have discussed the need and justification for specific goals and objectives and some procedural steps used in developing them.

Some additional steps were taken to finalize these objectives so that they could be better evaluated and implemented on the ground.

We developed a section on the impacts these objectives will cause on all resources. The major impacts were caused by the objective for managing some stands in an old-growth successional stage and by the objective for managing for a 40% level of cavity nesting bird habitat. Estimates of the impact from these two objectives varied from 7 to 12% falldown in annual timber yield. There were no other significant adverse resource impacts.

We also proposed an implementation plan whereby during a 10-year period, habitat would be inventoried on each of the 1,274 compartments in the four-Forest area. After the inventory, we will know exactly how each compartment measures up to the objectives and what form of habitat manipulation is needed to meet the objective.

We also developed a cost analysis of doing the basic inventory work and developed cost guides for annual coordination and monitoring. This analysis showed that the basic inventory would cost about $1,000 per compartment or about $0.20 per acre.

The goal and objectives that we developed for the four Forests of northeast Oregon were approved by the Forest Supervisors as guidelines for use in timber sale or other activity planning as well as land use planning.

We are using the guidelines to varying degrees on the Wallowa-Whitman National Forest. They will be used more in the future. With the Regional Snag Policy and the Regional Fish Habitat Management Policy these guidelines serve as bench marks for a more professional environmental analysis of a proposed project such as a timber sale.

ACKNOWLEDGEMENTS

I am grateful to Bill Knechtel, Ted Yarosh, and Bruce McMillan for improving this paper.

SPECIALIZED HABITAT REQUIREMENTS OF BIRDS:

SNAG MANAGEMENT, OLD GROWTH, AND RIPARIAN HABITAT[1]

Evelyn L. Bull[2]

Abstract.--Snags, old-growth forests, and riparian habitat are unique components of forest ecosystems. Their value, characteristics, and management as they relate to nongame birds are discussed.

INTRODUCTION

Forested lands in the Pacific Northwest provide a complex of environments and habitats. This variety of habitats is reflected in the number of animal species supported. It is important that resource managers work within the constraints of the forest ecosystem to preserve the diversity, permanence, and stability of the resources and thereby maintain our maximum options for the future.

Some forest components, namely snags, old-growth forests, and riparian zones, are of particular importance because of their unique characteristics. The role and management of snags, old-growth forests, and riparian zones, as they relate to birds in forest ecosystems, are discussed.

SNAGS AND THE HABITAT REQUIREMENTS OF WOODPECKERS

In the past, forest ecosystems have provided woodpeckers with the components, particularly snags, necessary for their survival. As time passes and management priorities change, forest ecosystems are altered. One alteration detrimental to woodpeckers is manifested as a shortage of snags and a decrease in the successional stages of snags or the surrounding forest. Forest management must be balanced so the forest ecosystem remains capable of supporting woodpeckers.

Value of Snags

Snags are used by birds for perching, feeding, nesting, and roosting. Feeding activity on snags is restricted primarily to the woodpeckers and nuthatches which forage for insects, superficially, in the bark and in the interior of the tree. Nest and roost cavities are used by a variety of birds, called cavity nesters. Woodpeckers and nuthatches, referred to as primary excavators, are capable of excavating holes. These cavities are in turn used as nest and roost sites by secondary cavity nesters, species which are not capable of excavating. There are 28 species of secondary cavity nesting birds which breed in Oregon and Washington (Jackman 1974) (table 1).

Without primary excavators to create holes, there would be extreme competition among secondary cavity users for the few existing natural cavities. With a shortage of nest sites, their densities would diminish (Haapanen 1963).

Cavity nesters are largely insectivorous and exert constant pressure on endemic insect populations which helps to prevent them from reaching epidemic levels (Bruns 1960, Beebe 1974). European countries have resorted to installing bird boxes in an attempt to increase cavity-nester populations and thereby decrease insect levels in forests (Franz 1961). This low cavity-nester population results from intensive timber management reducing or eliminating natural nesting sites, thus necessitating artificial cavities. These bird boxes will provide nest sites only for secondary cavity nesters as most woodpeckers will not utilize them.

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[1] Paper presented at the workshop on Nongame Bird Habitat Management in Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

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Definitions and Characteristics of Snags

For the purposes of this discussion, a snag is defined as any completely dead tree at least 10 cm (4 in.) in diameter at breast height (dbh) and greater than 2 m (6ft) in height. Although not discussed here, live trees with dead wood may serve the same role as snags.

Not all snags are alike in hardness, appearance, or physical characteristics. The condition of the dead tree is largely dependent on the agent which killed it. For example, the wood condition of a tree killed by a fungus is much different than one killed by lightning. The cause of death, species of tree, and the length of time the tree has been dead are important factors in determining the condition of the snag (Dahms 1949). The condition will change over time, generally deteriorating due to fungal infections. In turn, the condition of the snag dictates its value to snag dependent bird species. For the most part, snags with sound wood serve as sites for nest cavities, while deteriorating snags are generally used as foraging sites. Some woodpeckers (e.g., Lewis' woodpecker, downy woodpecker) are reported to excavate nest cavities in soft wood due to their inability to deliver strong blows (Jackman 1974).

Habitat Requirements of Woodpeckers for Nesting

Only the habitat requirements of woodpeckers will be dealt with here, based on the assumption that when the habitat requirements of excavators are provided, the habitat requirements of secondary cavity nesters are simultaneously satisfied. Table 1 lists the woodpeckers known to occur in the Pacific Northwest. Each species has specific requirements as to the forest types it will inhabit and the type of snags it will use for nesting (Jackman 1974, Conner et al. 1975). Tables 2 and 3 list those forest types in which each species is commonly found and the nest snag characteristics particular to the species[3] (Bent 1964, Jackman 1974).

Table 1--Avian cavity nesters which breed in Oregon and Washington (American Ornithologists' 1957, Jackman 1974).

Excavation

red-breasted nuthatch (*Sitta canadensis*)
white-breasted nuthatch (*Sitta carolinensis*)
pygmy nuthatch (*Sitta pygmaea*)
black-backed three-toed woodpecker (*Picoides arcticus*)
northern three-toed woodpecker (*Picoides tridactylus*)
white-headed woodpecker (*Dendrocopos albolarvatus*)
hairy woodpecker (*Dendrocopos villosus*)
downy woodpecker (*Dendrocopos pubescens*)
pileated woodpecker (*Dryocopus pileatus*)
yellow-bellied sapsucker (*Sphyrapicus varius*)
Williamson's sapsucker (*Sphyrapicus thyroideus*)
acorn woodpecker (*Melanerpes formicivorus*)
Lewis' woodpecker (*Asyndesmus lewis*)
common flicker (*Colaptes auratus*)

Nest in Cavities

wood duck (*Aix sponsa*)
common goldeneye (*Bucephala clangula*)
Barrow's goldeneye (*Bucephala islandica*)
bufflehead (*Bucephala albeola*)
harlequin duck (*Histrionicus histrionicus*)
hooded merganser (*Lophodytes cucullatus*)
spotted owl (*Strix occidentalis*)
sawhet owl (*Aegolius acadicus*)
screech owl (*Otus asio*)
pigmy owl (*Glaucidium gnoma*)
flammulated owl (*Otus flammeolus*)
sparrow hawk (*Falco spaverius*)
tree swallow (*Iridoprocne bicolor*)
black-capped chickadee (*Parus atricapillus*)
mountain chickadee (*Parus gambeli*)
chestnut-backed chickadee (*Parus rufescens*)
purple martin (*Progne subis*)
western bluebird (*Sialia mexicana*)
mountain bluebird (*Sialia currucoides*)

Sometimes Nest in Cavities

common merganser (*Mergus merganser*)
barn owl (*Tyto alba*)
starling (*Sturnus vulgaris*)
house sparrow (*Passer domesticus*)
violet-green swallow (*Tachycineta thalassina*)
house wren (*Troglodytes aedon*)
winter wren (*Troglodytes troglodytes*)
Bewick's wren (*Thryomanes bewickii*)
house finch (*Carpodacus mexicanus*)

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[3] Thomas, J. W., R. Anderson, C. Maser, and E. Bull. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

Table 2--Forest types characteristically inhabited by the woodpeckers in the Pacific Northwest[1] (Jackman 1974)

Woodpecker species	Occurrence by forest type								
	Oak	Riparian cottonwood	Aspen	Juniper dominant	Ponderosa pine	Mixed conifer	White fir	Lodgepole pine	Subalpine fir
Common flicker		X	X	X	X	X	X	X	X
Pileated woodpecker		X			X	X	X		
Acorn woodpecker	X								
Lewis' woodpecker	X	X			X				
Yellow-bellied sapsucker		X	X		X	X	X		
Williamson's sapsucker					X	X	X		
Hairy woodpecker					X	X	X	X	X
Downy woodpecker		X	X						
White-headed woodpecker					X	X			
Black-backed three-toed woodpecker						X	X	X	X
Northern three-toed woodpecker							X	X	X

[1] Thomas, J. W., R. Anderson, C. Maser, and E. L. Bull. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

Table 3--Minimum dbh and height of snags used for nesting by the woodpeckers in the Pacific Northwest [1] (Bent 1964).

Species	Minimum dbh in centimeters (inches)	Minimum height in meters (feet)
Common flicker	30 (12)	2 (6)
Pileated woodpecker	50 (20)	9 (30)
Acorn woodpecker	25 (10)	5 (15)
Lewis' woodpecker	30 (12)	9 (30)
Yellow-bellied sapsucker	25 (10)	5 (15)
Williamson's sapsucker	30 (12)	5 (15)
Hairy woodpecker	25 (10)	5 (15)
Downy woodpecker	15 (6)	2 (6)
White-headed woodpecker	25 (10)	2 (6)
Black-backed three-toed woodpecker	30 (12)	5 (15)
Northern three-toed woodpecker	30 (12)	5 (15)

[1] Thomas, J. W., R. Anderson, C. Maser, and E. L. Bull. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

Some of the woodpeckers are considered to be more specific or less adaptable in their habitat requirements than others; a few of these species are discussed.

The pileated woodpecker, the largest woodpecker occurring in the Pacific Northwest, requires a large diameter snag to contain its nest cavity (Bull 1975). It is important to maintain this species because its large abandoned cavities are used by the greatest variety and the largest of the secondary cavity nesters.

The white-headed woodpecker is local in occurrence and found in few areas. It is closely associated with stands of ponderosa pine (*Pinus ponderosa)* both for nesting and feeding (Ligon 1973). Its habit of nesting close to the ground in large ponderosa pine snags makes it more vulnerable to nest predation than other woodpeckers.

Little is known about northern three-toed and black-backed three-toed woodpeckers. They most frequently occur in mature and overmature stands of lodgepole pine *(Pinus contorta)* feeding heavily on bark beetle larvae (Koplin 1967). Of the two species, the black-backed three-toed woodpecker seems to be the more versatile in habitat selection.

Acorn woodpeckers are restricted primarily to oak (*Quercus garryana*) groves or mixed wood containing oak (Jackman 1974). This species is social, living in communal groups of 2 to 10 birds. Flycatching, sapsucking, and acorn storage are the primary foraging techniques. Nest sites are typically in mature oak or black cottonwood (*Populus trichocarpa*).

Management

Thomas et al. (see footnote 3) have devised a plan to manage woodpecker populations at different levels by manipulating numbers of snags. The following assumptions were used: 1) woodpecker numbers are limited by the number of snags available for nesting, 2) each woodpecker pair requires 1 to 3 sound snags (i.e., one nest, two roosts) each year, the number varying with the species, and 3) for every snag suitable for use, there are 15 that are not.

The number of snags needed by each species at its maximum potential population was computed as follows:

$$\begin{array}{c}\text{Number}\\ \text{snags per}\\ \text{40 hectares}\end{array} = \frac{\begin{array}{c}\text{Number}\\ \text{cavities}\\ \text{excavated}\end{array}\;\begin{array}{c}\text{15}\\ \text{unused}\\ \text{snags}\end{array}\;\begin{array}{c}\text{40 hec-}\\ \text{tares}\\ \end{array}}{\text{Territory size}}$$

Different population levels were computed by taking a percentage of the maximum. Table 4 lists the territory size and number of cavities used in the calculations.

Table 4--Territory size and number of cavities usually excavated by woodpeckers in the Pacific Northwest [1/] (Jackman 1974).

Species	Territory size in hectares (acres)	No. cavities excavated/year
Common flicker	16 (40)	1
Pileated woodpecker	120 (300)	3
Acorn woodpecker	4 (10)	1
Lewis' woodpecker	6 (15)	1
Yellow-bellied sapsucker	4 (10)	1
Williamson's sapsucker	4 (10)	1
Hairy woodpecker	10 (25)	1
Downy woodpecker	4 (10)	2
White-headed woodpecker	8 (20)	3
Black-backed three-toed woodpecker	30 (75)	3
Northern three-toed woodpecker	30 (75)	3

[1/] Thomas, J. W., R. Anderson, C. Maser, and E. L. Bull. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

Separate tables should be made for each plant community listing those woodpecker species occurring there and the number of snags required by each at different population levels. Table 5 lists the snag requirements of each woodpecker at the 100-, 70-, and 40-percent levels.

Table 5--Snag numbers needed to maintain woodpeckers at designated levels in the Pacific Northwest[1/].

Minimum snag size in centimeters (inches)	Species	Snags required per 40 hectares (100 acres) to support percentage of population maximum		
		100	70	40
		Percentage		
≥ 15 (6)	Downy woodpecker	300	210	120
≥ 25 (10)	Yellow-bellied sapsucker	150	105	60
	Acorn woodpecker	150	105	60
	Hairy woodpecker	180	126	72
	White-headed woodpecker	225	158	90
≥ 30 (12)	Common flicker	38	26	11
	Lewis' woodpecker	100	70	40
	Williamson's sapsucker	150	105	60
	Black-backed three-toed woodpecker	60	42	24
	Northern three-toed woodpecker	60	42	24
≥ 50 (20)	Pileated woodpecker	15	11	6

[1/] Thomas, J. W., R. Anderson, C. Maser, and E. L. Bull. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

Table 6--Snag numbers needed for woodpeckers in the ponderosa pine forest type in the Blue Mountains, Oregon [1]

Minimum snag size in centimeters (inches)	Species	Snags required per 40 hectares (100 acres) to support percentage of population maximum		
		100	70	40
		Percentage		
≥ 25 (10)	Hairy woodpecker	180	126	72
	White-headed woodpecker	225	158	90
≥ 30 (12)	Common flicker	38	26	11
	Lewis' woodpecker	100	70	40
	Williamson's sapsucker	150	105	60
≥ 50 (20)	Pileated woodpecker	15	11	6

[1] Thomas, J. W., R. Anderson, C. Maser, and E. L. Bull. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

Table 6 shows the number of snags needed to maintain woodpecker species occurring in the ponderosa pine forest type at 100, 70, and 40 percent of the maximim potential popula-
The 40-percent level is considered the minimum that will support a self-sustaining population.
tion. On the other hand, the 100-percent level would seldom if ever be reached as factors other than nest sites would act to limit the population.

This management plan assumed planned replacement over time as existing snags fall. Large snags may be substituted for smaller ones, thus lowering the number required. Snags should be left both in clusters and evenly distributed to maximize diversity. Location of snags should not be along roads within easy reach of woodcutters. The different woodpeckers show a preference for different tree species so a variety should be left.

Diversity is the essential concept. When given a choice, maintain maximum diversity in species, location, clustering, and characteristics of snags. Diversity of habitat will in turn provide diversity among cavity nesters.

OLD-GROWTH FORESTS

Much has been said about old-growth forests in the Pacific Northwest, and concern is growing over the continual whittling away of remaining old-growth forests. Old-growth forests are a specialized habitat, the components of which are important to many species of vertebrates. For the bird species, old growth is considered an optimum habitat rather than essential to their survival, as these species may occur in other successional stages in other areas but may be at lower densities or with reduced levels of survival and reproduction (Tanner 1942, Forsman 1975, Meslow and Wight 1975). Geographically, there are also variations as to how these species react to old-growth forests.

Value of Old Growth

Old growth is the final successional stage of a forest. Its retention is important for the maintenance of diversity and stability within the ecosystem. Diversity needs to be maintained for those species requiring or using this successional stage. Old-growth forests support reservoir populations which can disperse to other areas as the habitat becomes suitable allowing repopulation of areas which have lost their original populations.

A large number of birds use old-growth stands, the degree of dependency is unknown for most species. Meslow and Wight (1975) reported that 69 percent of those bird species occurring in Douglas-fir (*Pseudotsuga menziesii*) plant communities use old-growth forests. Over half of these species nest within that stage. Three species, the spotted owl (*Strix occidentalis*), goshawk (*Accipiter gentilis*), and Vaux's swift (*Chaetura vauxi*) nest primarily in old-growth stands. Of 118 bird species occurring in commercial forest types of the Blue Mountains of eastern Oregon and Washington, 69 percent reproduce in old-growth forests and 80 percent forage there. Figure 1 demonstrates the importance of old-growth forests as a successional stage for reproduction and feeding in birds found in the Blue Mountains.

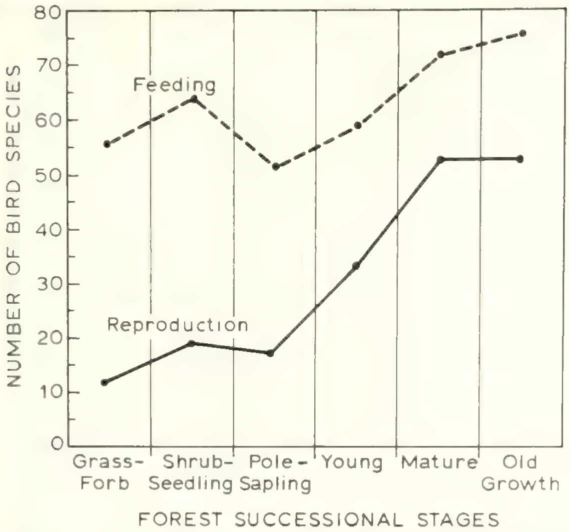

Figure 1.--Number of birds utilizing forest successional stages for nesting and feeding in the Blue Mountains, Oregon.

Old growth is a specialized habitat; consequently those species associated primarily with it have become adapted to it. Some of these birds include: great gray owl (*Strix nebulosa*), barred owl (*Strix varim*), flammulated owl, white-headed woodpecker, northern three-toed woodpecker, and Townsend's warbler (*Dendroica townsendi*).

Definitions and Characteristics

A precise definition describing all old-growth forest stands in the Pacific Northwest is difficult to formulate. Old-growth stands west of the summit of the Cascade Range are generally Douglas-fir and hemlock (*Tsuga heterophylla*); while east of the summit, ponderosa pine, mixed conifer, and lodgepole pine form stands of old growth. Although the tree species differ with locality, the structural composition is the key factor in old-growth habitats. Characteristics and their related functions considered typical of old growth are listed below.

1. At least 37 of the largest overstory trees per hectare (2.5 acre) exceed 50-cm (20-in) dbh in mixed conifer and ponderosa pine stands and 15-cm (6-in) in lodgepole pine stands. Large overstory trees are used for nest sites by the large owls and goshawks. Large trees become large snags which are critical to pileated woodpecker reproduction.

2. Canopy is uneven-aged, multilayered, and relatively closed. These different canopy layers provide a dense forest environment, yet the individual layers are not so dense as to impede flight (Forsman 1975). A variety of microclimates are available within the different layers.

3. Level of standing and down, dead woody material is high. Standing dead wood provides nest and roost sites for cavity nesters, while the downed material is used for foraging.

4. A relatively high degree of decadence includes heart rot, mistletoe, and diseased trees. Decadence results in a greater diversity of conditions and therefore species using those conditions.

5. Ages generally accepted as comprising structural old growth are: 80+ years in lodgepole pine, 120+ years in Douglas-fir, 160+ years in mixed conifer, 200+ years in ponderosa pine.

Management

Attempts to manage old growth have resulted from either dedication or allocation. Dedication refers to the permanent retention of areas in old growth; allocation refers to an area managed in old growth for a specified time span. Most of the land which has been set aside for old growth is in National Parks or State and Federal resource natural areas.

The Wallowa-Whitman, Malheur, Umatilla, and Ochoco National Forests are using guidelines for the perpetuation of old growth on Forest Service lands. These guidelines were designed to retain enough old-growth habitat to maintain at least self-sustaining populations of each existing species occurring there. Five percent of the total of each timber type will be managed as old growth (i.e., ponderosa pine, mixed conifer, and lodgepole pine). Areas of old growth are to be dispersed in the tri-compartments (i.e., management units, approximately 2600 ha [6300 acres] in size) to decrease chances of major loss to fire, insects, or disease and to maximize the distribution of old growth. Stands will be no less than 8 hectares (20 acres) in size with preference given to stands of 40 hectares (100 acres) and above. Management of this type will insure diversity over a large area by providing for the continued existence and replacement of old-growth stands.

RIPARIAN HABITAT

Riparian habitat is an extremely critical and unique type. Riparian makes up the smallest percentage in land area of the habitat types, yet it is the most important habitat to wildlife whether it is in the Coast Ranges or on the desert.

Value of Riparian Zones

A diversity of birdlife is possible because of the diversity of habitat components within riparian zones. This diversity enhances the richness and stability of the ecosystem over time and space.

Riparian zones are primary activity centers of birds and contain higher bird densities than areas without a water influence (Gill et al. 1974). Hooper (1967, cited in Curtis and Riley 1975) found 44 percent more breeding birds and 33 percent more individual bird species along transects adjacent to a stream than he found on midslope away from the stream. Johnson (1970) reported riparian zones to support the highest population densities for non-colonial nesting birds. In an arid environment, riparian zones are unique in terms of avifaunal productivity, and the survival of a large number of species is dependent upon those areas (Carothers and Johnson 1975). In a study along the Verde River, Carothers and Johnson[4] concluded that 56-percent of the species breeding in homogeneous cottonwood stands were exclusively dependent on that habitat for reproduction.

Definitions and Characteristics

Riparian zones are those areas influenced by water. The water influence can be attributed to a variety of water bodies including: streams, ponds, seeps, rivers, lakes, springs, bogs, and wet meadows. There is characteristically great diversity between riparian zones because of the differences in water bodies and the variability in the surrounding areas, namely topography, plant communities, soils, gradients, etc.[5]

Riparian zones are extremely important to many bird species for a variety of reasons. The three critical habitat components of all species are food, cover, and water. Riparian habitats often provide all three.

The water influence enables a greater plant biomass, faster growth, and a greater plant diversity than more xeric sites. A combination of these factors results in a diverse vegetational structure and a multitude of horizontal and vertical stratification. The water, its associated vegetation, and the differing stages progressing from the water create continuous edge effects which further add to the diversity (fig. 2.) This diverse foliage strata and abundance of edges increase the number of niches available for birds (Fawver 1950, cited in Curtis and Riley 1975).

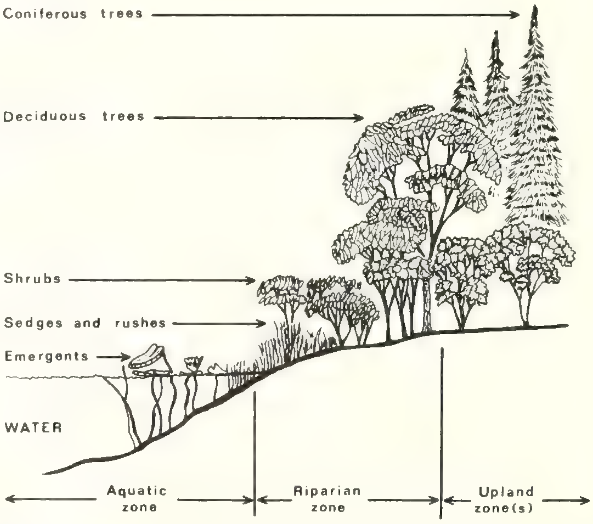

Figure 2.--The riparian zone is characterized by different stages or levels of vegetation progressing from the water[6]

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[4] Carothers, S. W., and R. R. Johnson. A summary of the Verde Valley breeding bird survey. 1970. Unpublished information.

[5] Thomas, J. W., C. Maser, and J. E. Rodiek. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

[6] Thomas, J. W., C. Maser, and J. E. Rodiek. Unpublished data on file at the Pacific Northwest Forest and Range Experiment Station, Range & Wildlife Habitat Laboratory, La Grande, Oregon.

Vegetation diversity along riparian zones greatly adds to the diversity of avifauna, because the vegetation is often unique to that particular zone. For example, most of the deciduous vegetation in the Blue Mountains is contained in riparian zones and those birds dependent on deciduous vegetation occur only there.

Some riparian zones, particularly streams and rivers, provide travel lanes or connectors between habitat types. These waterways are used by a variety of birds during migration and daily movements.[5]

Riparian zones are unique critical habitats; and because of their structure, diversity and edge components are extremely sensitive to manipulation. The components of this system which make it valuable to birds also make it desirable to a variety of other disciplines including: recreational areas, road construction, timber harvest, and grazing.[5]

All these factors seriously alter riparian zones by increasing disturbance, trampling, erosion and sedimentation, compaction, loss of ground cover and water quality, and alteration of vegetational structure. Any of these factors could detrimentally affect riparian zones for bird habitation. Carothers et al. (1974) found 46 percent fewer breeding birds in a homogeneous cottonwood riparian zone which had been thinned to 25.4 trees per hectare (10.3 trees per acre) than he found in a similar but undisturbed area with 115.1 trees per hectare (46.6 trees per acre).

Management practices which have been aimed at minimizing the effects of disturbance have met with varied acceptance. Probably the most widely used is the retention of buffer strips (i.e., undisturbed strips of land adjacent to water zones) between harvest operations or roads and streams. These buffer strips are aimed at maintaining water temperature and quality and preserving stream channel integrity and associated riparian vegetation (Kochenderfer, J. N. 1970, cited in Carothers and Johnson 1975).

Planting of shrubs and the artificial channeling of streams has been done in disturbed areas to regain some of the diversity and edge effect that had been lost.

This discussion is not to imply riparian zones are not to be managed, rather it is to demonstrate the great diversity and sensitivity characteristic of these areas. A great deal of care must be used in managing riparian zones because of the great complexity of that ecosystem.

CONCLUSION

Snags are an essential habitat component for cavity nesting birds.

Old-growth forests are a very specialized habitat supporting species which have become specifically adapted to it.

Riparian zones, comprising the smallest percentage in land area of the habitat types, are the most widely used by wildlife.

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ACCOUNTING FOR NONGAME BIRD HABITAT IN LAND USE PLANNING[1]

Paul R. Canutt, and John H. Poppino[2]

Abstract.--The U.S. Forest Service's land use planning process is reviewed from its inception to the present, with reference to significant laws and public attitudes that have molded current procedures. Techniques for displaying and evaluating nongame bird habitat needs in relation to total land use needs are examined for two land use planning units.

INTRODUCTION

Land Management (Use) Planning on National Forests probably began with the first Ranger as he sat on his horse at a vantage point and determined which other peaks would make good lookout points for fire detection. From this beginning, planning progressed through functional resource "development" plans in the 1910-1940 period. Continually increasing demands for all forest resources and the addition of new laws increased the sophistication of the planning process.

With the enactment of the Multiple Use-Sustained Yield Act in 1960, emphasis began shifting from functional to multifunctional planning for water, timber, recreation, wildlife, and forage resources. This act called for Multiple Use Plans to provide for the conservation and management of the named resources. Planning was generally done by one man with the information readily available, and plans were almost all prepared from a forester's viewpoint as few other professionals were employed then.

In 1969 the National Environmental Policy Act was passed. This Act called for an interdisciplinary analysis of all "significant Federal actions." Land use planning was determined to come under this Act.

In 1976 the National Forest Management Act was enacted. This Act directs that Interdisciplinary Teams will be used in the development of land and resource management plans.

Because of the increased activity on the National Forests, land use planning is necessary for several reasons. These lands have a wide variety of values which are important to members of our society.

One of many conflicting value issues concerns timber harvest and natural values. When these lands were first placed under the jurisdiction of the Forest Service many years ago, there was little pressure to develop lands for timber production. Management emphasis was placed on protecting existing forest values, including existing wildlife, recreation, and timber volumes. As time passed, the economic value of timber increased and the timber productivity potential received more attention by forest managers.

This emerging emphasis on timber management has evolved into public controversy about how the lands on the National Forests will be allocated and managed. The controversy stems from different segments of the public having different views of the function and goals of the National Forests in our society. Those favoring the management of the National Forests for high levels of timber output see this potential of the Forests being expressed in the form of old-growth timber and the flow of timber currently being harvested. Those favoring the management of the National Forests for the Forests' natural values and their associated amenities see these values in the Forests now and oppose any activities that will change them.

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[1] Paper presented at the Workshop on Nongame Bird Habitat Management in the Coniferous Forests of the Western United States, Portland, Oregon, February 7-9, 1977.

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PLANNING PROCESS

National Forest lands can support a wide variety of uses and produce a wide variety of social values. Some of these uses are compatible with other uses; some are not.

One goal of land use planning is to identify the capability of the land to be used for various purposes and the suitability of these uses from the social, ecomonic, and ecological standpoint.

The Unit Plan is the specific planning document used to provide an assessment of land capability and an evaluation of alternative land allocations.

Unit Planning is part of the problem solving process that develops information needed by management teams in making decisions. It addresses the question, "What is it possible to do on these lands?", and answers the question, "What will be done on these lands?"

For the planning to be effective, the decisions must be based on interdisciplinary analysis of resource information. Unit Plans must be quantified to the point where trade-offs between alternatives can be well understood by the planners, the management team, and the public. It is important to identify what opportunities are open, which opportunities are closed, and what kind of outputs can be expected from each alternative.

In identifying "what will be done on these Forest lands," several decisions are made in the unit planning process. A major decision is that of land classification. The unit plan identifies how the land will be used and how the resources will relate to each other as a result of land classification. This evaluation of resource interrelationships is based in the suitability of the land for compatible and conflicting uses of all the resources identified in the unit.

Alternatives for managing a planning unit within its limits of capability and suitability are developed by land managers working with unit planners and interested individuals. Alternatives are formulated in an effort to meet as many of the unit planning goals as possible. Methods are also used to analyze the trade-offs and consequences of the alternatives in attempting to meet the goals. Linear programming and goal programming techniques are useful in measuring the level of attainment of the various alternatives. Other methods of analysis such as multiple overlays may be used, providing the differences in attainment are quantified.

The Forest Supervisor or other responsible official chooses the management strategy to be implemented on the unit. He does this within the National Environmental Policy Act process. After reviewing public comment from the draft environmental statement, he proposes what he judges to be the most desirable alternative considering public comment, national goals, regional goals, and land capability. This proposal is documented in the Final Environmental Statement. At least 30 days[3/] after the Final Environmental Statement has been filed with Council on Environmental Quality, he again considers public response and makes a decision to implement or modify the proposed alternative.

We have provided an overview of land use planning from its inception, which involved simple decisions by usually one person, to today's multifunctional decisionmaking processes by a team of interdisciplinary experts working with strong involvement from the public. It is this latter phase that we will deal with in the remainder of our discussion.

NONGAME BIRD MANAGEMENT

Land use planning in the current sense started in 1970, and the first final environmental impact statements for the unit plans were filed with the Council on Environmental Quality in 1974. An examination of wildlife information in the unit plans from the earliest to the present, provides documentation of the state-of-the-art in nongame bird habitat management on National Forest lands. During the first years, new ground was being broken so there was little direction on ways to use or display available information on nongame birds. In short, we were not able to adequately predict consequences of different land use alternatives on wildlife.

None of the early plans offered concrete management direction or allocation of habitat specifically to meet the needs of nongame birds.

Fortunately several changes have occurred in the intervening years that have enabled us to treat nongame bird habitat needs more adequately, or at least to display and discuss the impacts of different land use alternatives on nongame birds.

[3/] Decisions on Unit Plans containing roadless areas are not implemented until Congress has had 90 days in session to consider wilderness legislation.

Early in this decade we experienced a change in public attitude toward wildlife. Concern was expressed for the need to manage nongame wildlife. No longer was the term wildlife synonymous with big game and upland game, as it had been for so many years. State game departments reacted by dropping the word "game" from their titles, and inserted "wildlife;" nongame biologists, although in restricted numbers, were recruited into both State and Federal Agencies, and program direction in the agencies began to reflect modest consideration for nongame needs.

Interest in nongame bird management was further stimulated in May 1975 by a nationally prominent symposium at Tucson, Arizona, which dealt with the management of forest and range habitats for nongame birds. This was an event of historical wildlife significance in that it was the first time avian ecologists and resource managers had come together to relate scientific aspects of nongame bird studies to land management practices.

Finally, and in our opinion, the most important event affecting our ability to input wildlife needs into the land use planning process was the development of a publication titled, "Forest Wildlife Relationships in the Blue Mountains of Washington and Oregon."4/ This document is the product of an intensive State-Federal effort. It serves the land managers needs in several ways.

1. It provides a broad, but specific, data base that gives biological information well beyond the personal knowledge level of an individual biologist.

2. It is organized in such a way that the land manager can use it for predicting consequences of land treatment at several detail levels, ranging from individual species to broad groupings of species with similar habitat needs.

3. It contains basic information needed to develop guidelines or policy for managing the wildlife resource.

The Forest Wildlife Relationships document is specific to the Blue Mountain area of Washington and Oregon, but its basic arrangement and utility has universal application. Adaptation to other geographic areas can be made by deleting information on inappropriate species, habitat niches, plant communities and land types, and adding information relevant to the concerns of the other geographic areas.

Incorporating Wildlife Needs into Land Use Plans

In managing wildlife habitat, the land manager should be concerned with two general concepts. These are species richness or diversity and featured species habitat management. The first concept insures that habitat is provided for all wildlife species in each ecosystem, and the second allows for production emphasis on species important in the recreational use of National Forest lands.

Additionally, land use plans provide for wildlife habitat in two ways. They incorporate administrative direction and regulations which provide for the coordination of wildlife needs with other resources. Examples are Regional and Forest snag management policies, fish habitat management policies, the National Forest Management Act, and regulations to protect threatened and endangered species. Secondly, when necessary, direct allocation of land is made to meet the needs of a species or group of species. An example is the allocation of old-growth timber specifically to meet wildlife habitat requirements.

Oregon Butte Land Use Plan

The Umatilla National Forest planning team has effectively used this approach and has drawn extensively upon information in the Forest Wildlife Habitat Relationships in preparing the Oregon Butte Land Use Plan (U.S. Forest Service 1976).

The team integrated wildlife into the planning process using two assumptions. These were:

1. Estimates of the numbers of animals produced by a given resource allocation type are related directly to the habitat opportunities provided. The allocation type is defined as the mix of land use management activities occurring on the same piece of land.

Identified public values and management objectives were used to develop the allocation types for the Oregon Butte Plan. Examples of two allocation types

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4/ Thomas, Jack W., et. al. This document is presently in pre-publication format. Anticipated date of final publication by the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon is late 1977.

are "Resource Production - Basic," and "Resource Production - Woodpecker." Areas assigned "Resource Production - Basic" emphasize production of wood fiber and domestic livestock with wildlife habitat management at a minimum level. Conversely, areas assigned "Resource Production - Woodpecker "provide near optimum pileated woodpecker habitat with lower wood fiber and domestic livestock production. Wildlife impacts resulting from each allocation type are rated from 1 through 0, as shown in table 1. If the resource uses in an allocation type prevent the maintenance of any habitat for an indicator species, it is rated 0. The "Resource Production - Woodpecker" allocation type has a rating of 0.75 which indicates that sufficient habitat is maintained in the allocation type to provide 75 percent of optimum population levels.

Table 1.--Effects of Allocation Types on Bird Habitat.

Allocation Type	Pileated Woodpeck.	Goshawk	Three-toed Woodpeck.
Resource Prod. & Limited Access			
Basic	0.	0.	.40
Visual	.75	0.	.45
Streamside	.75	0.	.45
Elk	0.	0.	.40
Goshawk	.85	1.0	.90
Woodpecker	.75	0.	
Backcountry	1.0	1.0	1.0
Wilderness Study	1.0	1.0	1.0
Developed Sites	0.	0.	0.
Regional Rec.	0.	0.	0.
Special Mgt.	1.0	1.0	1.0

2. The second assumption was that species most sensitive to habitat manipulation can serve as indicators for other species with similar but less restrictive habitat needs. Four species were selected to represent all wildlife species in the planning unit:

a. General forest users were represented by elk.
b. Snag or cavity users were represented by the pileated woodpecker.
c. Old-growth users were represented by the goshawk.
d. Subalpine timber users were represented by the northern three-toed woodpecker.

Essential biological requirements were then identified for each of the four indicator groups. Biologists on the planning team selected the following criteria for the pileated woodpecker and the group of animals it represented:

1. Ponderosa or ponderosa and associated timber stands.

2. Two to four standing snags per acre larger than 12" DBH and taller than 15 feet.

3. One to two down trees per acre at least 12 inches DBH.

4. One 5-acre patch of old growth in which the majority of trees exceed 30" DBH, within the territory of each potential pair of pileated woodpeckers. The territory size used was 640 acres, which calculates to .0031 birds per acre at optimum levels.

The final piece of information used to develop coefficients for determining potential animal numbers for the various resource use allocations was the landtype inventory. Landtypes are defined as units of land with similar vegetative, soil, and landform characteristics and capabilities, which respond similarly to management activities. They are the base units in which all resource data for the planning unit are stored. Table 2 reflects the manner in which characteristics of each landtype influence species numbers. For example, landtype 3c is only 25-percent forested, so under optimum conditions it is capable of producing approximately one quarter as many pileated woodpeckers as the fully timbered landtype 6b which has a habitat usability rating of 0.9.

Expression of the potential influence of a given resource allocation for a landtype can now be expressed numerically in animal equivalents by multiplying the potential number of pileated woodpeckers per acre (.0031) by the productivity capability for the landtypes (6b = 0.9), and in turn by the productivity limitation for a specific allocation type (Resource Production - Woodpecker 0.75). The result equals the number of woodpecker per acre. This figure is then converted to actual potential when multiplied by the acres in the landtype.

(.0031) (0.9) (0.75) = 0.0020825 - woodpeckers/ac.)
(8330 ac. in landtype) = (17 - number of woodpeckers potentially produced in the landtype.)

Table 2.--Productivity Capabilities by Landtype for Bird Habitat.

	Percentage of Landtype Capable of Producing Habitat		
Landtype	Pileated Woodpecker	Goshawk	Three-toed Woodpecker
1	.1	0.	.0
1a	0.	0.	.0
2	.2	.2	.0
3	.25	.55	.0
3c	.25	.35	.0
4	.5	1.0	.1
4a	0.	.5	.25
5	.2	.6	.0
5a	0.	.5	.5
5b	.65	.2	.0
6	.20	.8	.5
6a	.10	.7	.7
6b	.90	.8	.0
7	.15	.8	.25
7b	0.	.65	.55
8	.2	.85	.5
9	.75	1.0	.0
10	.5	1.0	.0
11	.6	.9	.0
11a	0.	.1	.05
22	0.	.0	.0

The array of land use alternatives offered for public review can be ranked and displayed for wildlife, as shown in table 3, by totaling the animal equivalents of indicator species for each landtype in the planning unit. Differences in production between alternatives is accounted for by the different combinations of resource allocation types used to develop each land use alternative. Alternative E, which is strongly commodity oriented, reflects reduced wildlife production. Conversely, the amenity Alternative A produces much higher wildlife outputs. Table 3 also displays relative impacts between indicator groups. For example, in Alternative E, production of pileated woodpeckers is 26 percent lower than the production in Alternative A. However, the impact on goshawks between Alternative A and E amounts to a 52 percent reduction, because of the goshawks greater requirement for old-growth timber.

Table 3.--Outputs by indicator species in animal equivalents and the relative ranking of each alternative based on potential populations.

Wildlife Populations **(In animal equivalents)**

Indicator Species	ALTERNATIVE								
	A	B	C	D	E	F	G	H	I
Elk Output	9450	9730	8380	7740	7730	9850	9700	9750	9670
Pileated Woodpecker Output	228	225	181	175	168	216	215	215	215
Goshawk Output	27.0	27.0	14.3	16.5	13.0	27.0	20.0	20.0	20.0
Three-toed Woodpecker Output	592	520	438	438	408	505	504	506	506

Table 4 summarizes the outputs for all recognized opportunities on the planning unit. This technique allows our publics an opportunity to evaluate land use alternatives in respect to trade-offs between the various resource outputs and opportunities. In turn, the land manager will have input from a better-informed public to use in making final land use decisions.

Table 4.--Summary of outputs and potentials by land use alternative.

Outputs/ Opportunities	ALTERNATIVE								
	A	B	C	D	E	F	G	H	I
Sediment Ac. Ft.	54.2	55.4	58.4	58.6	59.8	56.0	57.1	56.5	56.5
Water M Ac. Ft.	875	876	878	878	878	876	877	877	877
Wildlife/Elk AE	9450	9730	8380	7740	7730	9850	9700	9750	9670
Wildlife/Goshawk AE	27.0	27.0	14.3	16.5	13.0	27.0	20.0	20.0	20.0
Wildlife/Pil. Woodpecker AE	228	225	181	175	168	216	215	215	215
Wildlife/3-Toed Woodp. AE	592	520	438	438	408	505	504	506	506
Forage/Cattle M AUM	7.10	7.54	8.43	8.52	8.63	7.64	7.85	7.73	7.73
Woodfiber MM Bd. Ft.	29.9	33.4	44.1	45.7	48.0	36.0	37.8	37.7	37.7
Recreation/Type I M RVD	52.4	41.8	27.0	26.9	22.5	40.6	38.7	39.1	20.0
Recreation/Type II M RVD	106.9	109.9	89.7	81.8	79.2	105.3	104.9	103.0	107.4
Recreation/Type III M RVD	185	189	186	182	182	191	192	191	191
Employment/Woodfiber Jobs	476	531	702	727	764	573	602	600	600
Employment/Recreation Jobs	458	456	434	425	421	453	453	455	453
Employment/Grazing Jobs	40	42	47	48	49	43	44	43	43
Return to Counties M$	104	113	148	158	162	120	124	122	122
Return to Treasury M$	162	172	223	246	244	182	184	178	178
Backcountry M Ac.	44	229	128	115	0	35	170	118	171
Wilderness Study M Ac.	197	0	0	0	0	171	0	53	0

Silvies-Malheur Land Use Plan [5]

The Malheur National Forest planning team has used a fish and wildlife habitat analysis index for measuring the effects of alternative resource allocations on wildlife. Eight major habitat management goal categories are covered in the index. They include (1) Forest Succession Guidelines, (2) Snag Management Guidelines, (3) Elk and Deer Habitat Guidelines, (4) Water Quality Standards, (5) Riparian Zone Guidelines, (6) Forage Management Guidelines, (7) Threatened and Endangered Species Protection, and (8) Special Habitat Requirements.

Some of the index elements have been extracted and are shown in table 5. The index is based on the assumption that land use alternatives vary in their ability to meet fish and wildlife habitat goals. To measure these variations, a numerical rating system from 1-5 is used. A rating of 1 indicates minimum goal attainment, whereas a rating of 5 means complete fulfillment of a particular goal.

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[5] The Silvies-Malheur Land Use Plan Draft Environmental Impact Statement is scheduled for public release in the spring of 1977.

The goals identified in the left side of the matrix represent a mixture of habitat diversity objectives, featured species needs, management policy, and management guidelines. Fifty-four specific wildlife goals were analyzed for the Silvies-Malheur planning unit, so a rating of 270 points is possible if an alternative completely meets all wildlife goals. Each alternative can then be compared against other alternatives for its ability to meet either specific wildlife goals or the aggregate of all 54 goals.

Table 5.--Fish and wildlife habitat index.

GOALS	Alternatives				
	Present Situation	Alternative A	Alternative B	Alternative C	Alternative D
A. Forest Succession Guidelines: On each Total Resource Inventory compartment unit of approximately 8,000 acres or less, major timber types will be identified and plans made for at least 5% of the total of each timber type to be disturbed at times in each of the following stages.					
1. Grass-Forb-Seedling: 0-½" DBH, 0-10 years	5	5	5	5	5
2. Pole-Sapling:					
Fir ½-8" DBH, 11-35 years	5	5	5	5	5
Succ. Pine ½-8" DBH, 11-30 years	5	5	5	5	5
Climax Pine ½-8" DBH, 11-50 years	5	5	5	5	5
Lodgepole ½-4" DBH, 11-30 years	5	5	5	5	5
3. Young:					
Fir 8-16" DBH, 36-70 years	5	5	5	5	5
Succ. Pine 8-16" DBH, 31-70 years	5	5	5	5	5
Climax Pine 8-16" DBH, 51-110 years	5	5	5	5	5
Lodgepole 4-14" DBH, 31-79 years	5	5	5	5	5
4. Mature:					
Fir 16-20" DBH, 71-90 years	5	5	5	5	5
Succ. Pine 16-20" DBH, 71-100 years	5	5	5	5	4
Climax Pine 16-20" DBH, 111-180 years	5	5	5	5	4
Lodgepole 14-16"+ DBH, 80-100 years	5	5	5	5	5
5. Old Growth:					
Fir 20"+ DBH, 90 years +	3	5	4	4	2
Succ. Pine 20"+ DBH, 100 years +	3	5	4	4	2
Climax Pine 20"+ DBH, 181 years +	3	5	4	4	2
Lodgepole 16"+ DBH, 100 years +	3	5	4	4	3

The Malheur planning team is also developing a biological assessment of the response of life forms to land management alternatives. Species or groups of species having similar requirements for reproducing and feeding can be said to belong to the same life form. Based on reproduction and feeding requirements, 16 life forms have been identified for the Malheur National Forest. Two examples are species that excavate their own holes in trees and feed on the ground, in bushes, trees, or air, and species that reproduce in water and feed on the ground, in bushes, and/or trees.

Figure 1 demonstrates a sample matrix for displaying estimated changes in wildlife populations, as related to their maximum potential, for the 16 life forms and five land use alternatives in the plan. Estimated percent change in life forms was based on predicted response of a life form to other management objectives for the various alternatives. For example, life form 13, which includes those species that excavate their own nest in trees, is presently being maintained at 60 percent of its population. Alternative A emphasizes fish, wildlife, and wilderness, thereby ultimately providing habitat to maintain the population at its full potential. Alternative D allocates more land to timber production. The high timber output targets in alternative D also require silvicultural treatment that cannot permit snag management at high levels. Therefore, snag-dependent wildlife would be maintained at 40 percent of their potential.

The effects of alternative resource allocation and management direction on the remaining 15 life forms can be determined in a similar way. The end product will then provide an overall summary of positive and negative impacts on all wildlife afforded by each land use alternative.

Figure 1.--Sample matrix showing estimated percent change in wildlife populations by life form and alternative as related to maximum potential

Life	Present	Alternative			
Form	Situation	A	B	C	D
1					
2					
3					
4					
5					
7,					
12					
13	60	100	75	65	40
14					
15					
16					
Total					

SUMMARY

The degree to which nongame bird habitat needs are being incorporated into the land use planning process has progressed significantly in the past 2 years. This has been due largely to increased concerns by both the public and land managers and to development of analytical techniques.

We have discussed two plans which used the "Forest Wildlife Relationships in the Blue Mountains of Washington and Oregon." The Umatilla National Forest related the number of animals produced in a given habitat type to the habitat opportunities available. They also assumed that the species most sensitive to habitat manipulation could serve as indicators for other species with similar but less restrictive habitat needs. The Malheur National Forest developed a fish and wildlife habitat analysis index for measuring the effects of alternative land allocations on wildlife. Their basic assumption was that land use alternatives vary in their ability to meet fish and wildlife habitat goals. Both approaches enable the reviewer to compare impacts of land use alternatives on wildlife.

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EDGES—THEIR INTERSPERSION, RESULTING DIVERSITY AND ITS MEASUREMENT[1]

Jack Ward Thomas,[2] Chris Maser[3] and Jon E. Rodiek[4]

Abstract.—Edge can be a crude measure of overall diversity of any area. Diversity is considered as inherent (community/community) edge, induced (successional stage/successional stage) edge and total edge. Size of forest stands are related to expected wildlife diversity.

INTRODUCTION

Definitions

Leopold (1933:132) was probably the first person to concisely understand and state that "game [wildlife] is a phenomenon of edges." He said that wildlife "occurs where the types of food and cover which it needs come together, i.e., where their edges meet.... We do not understand the reason for all of these edge-effects, but in those cases where we can guess the reason, it usually harks back to the desirability of simultaneous access to more than one environmental type, or the greater richness of border vegetation, or both."

Laws of Dispersion and Interspersion

The food-cover-wildlife relationships have been called the laws of dispersion and interspersion. The law of dispersion is that potential density of wildlife with small home ranges that require two or more habitat types is roughly proportional to the sum of the type peripheries (Leopold 1933, Dice 1931). Kelker (1964:181) paraphrased the law on interspersion, "Abundance of resident species requiring two or more cover types appears to depend on the degree of interspersion of numerous blocks of such types." An edge, as we are using the term, is that area where two or more plant communities or successional stages within plant communities meet.

EDGES

Types of Edges

We will consider two types of edges, inherent edges and induced edges.

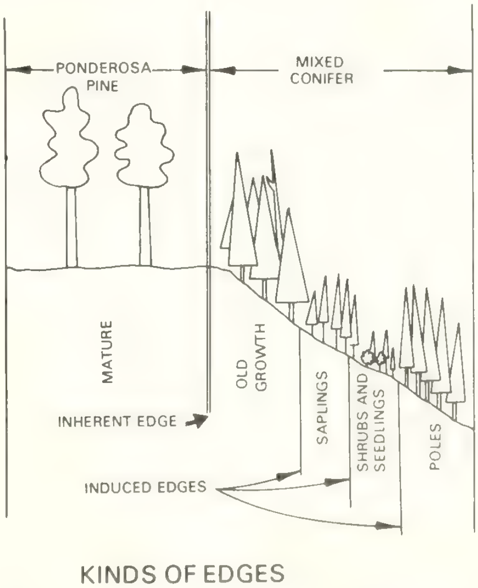

Figure 1.—Edges are created where plant communities meet or where successional stages or conditions within communities meet.

Inherent Edges

An inherent edge is either an abrupt change in environmental conditions, i.e., soil type which placed different plant communities in juxtaposition or a mosaic change in environmental conditions resulting in the interdigitation of plant communities. The former normally has a rather abrupt edge. In the latter, however, a continuous plant community becomes broken up into islands and peninsulas which gradually intermix with islands and peninsulas of another plant community until once again a community becomes a continuous entity.

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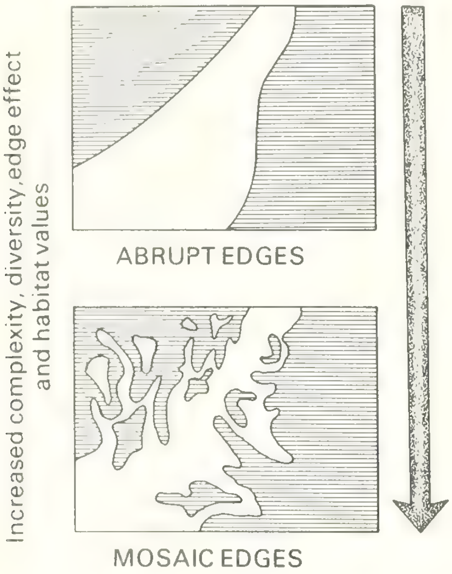
Increased complexity, diversity, edge effect and habitat values
ABRUPT EDGES
MOSAIC EDGES

Figure 2.--Inherent edges may be abrupt or mosaic and are long-term components of the land base.

Inherent edges are long-term components of the land base. Plant communities are an expression of the integration of site factors (Daubenmire 1976). The four most obvious natural factors (fig. 3) that cause and affect inherent edges are:

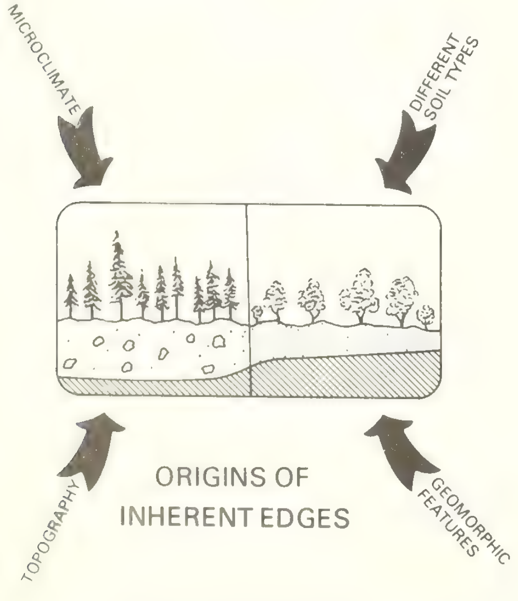

Figure 3.--Some primary causes of inherent edges.

1. Abrupt differences or changes in soil type.
2. Extremes in topography (steep elevational gradients, deep canyons, slope aspects, or rain shadow effects).
3. Geomorphic features, such as extrusive rock outcrops, lava flows, and glacial deposits.
4. Microclimate--differences in temperature and moisture regimes near the ground level.

Differences in microclimate repeatedly change the environment, favoring one plant community or another. Over time, these shifts sometimes create a mosaic edge between plant communities.

Induced Edges

Induced edges, under natural conditions, are created by drastic but short-term environmental factors, such as fire, disease, flooding, and erosion. These factors tend to shift the affected plant communities toward earlier, less mature successional stages (fig. 4).

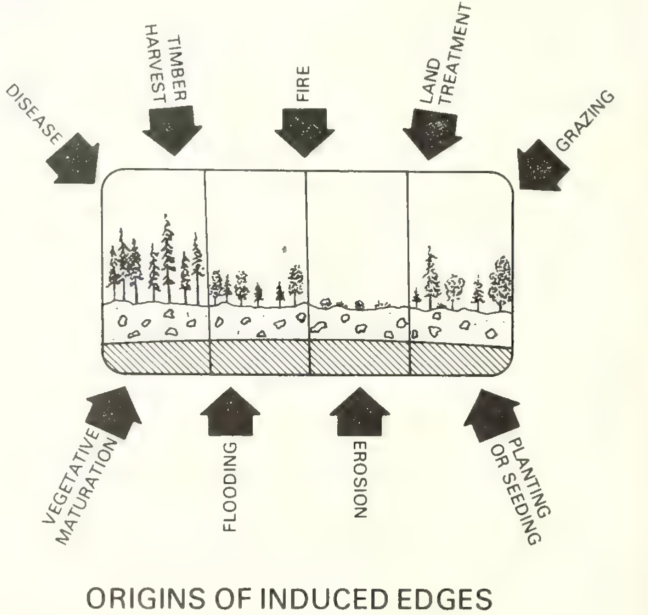

Figure 4.--Some primary causes of induced edges.

As a result, induced edges are temporary, lasting from a few years to many years. They are not a permanent feature of the landscape.

Biological Importance

The biological importance of edge may be expressed in the term "richness." Edges are rich in wildlife because of the additive effect on the fauna when two plant communities or successional stages meet. There is a mingling of the species common to each type plus the addition of any species that may be a direct product of the circumstances of the edge itself. This is graphically shown in figure 5.

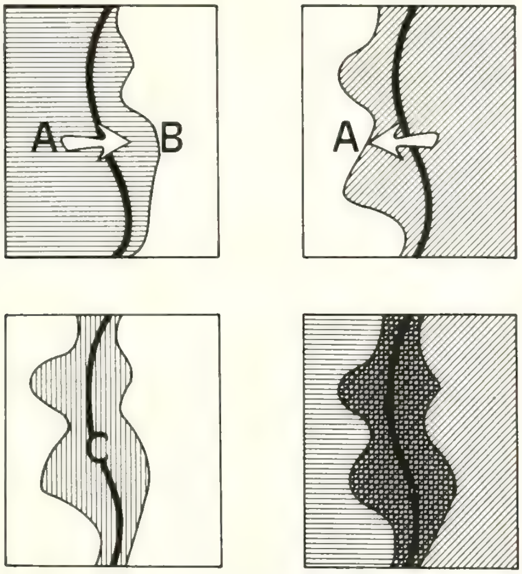

Figure 5.--The species richness may be considered as an additive effect.

In another sense the richness is related to the diversity expressed in the edge (fig. 6). More about this later.

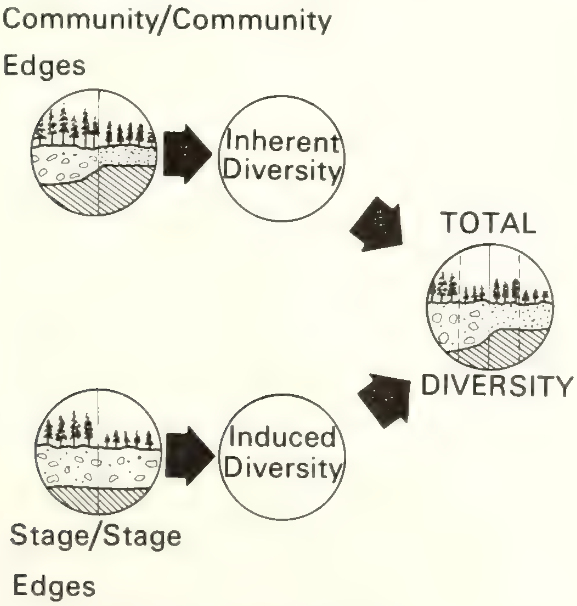

Figure 6.--The amount and arrangement of edge is an expression of habitat diversity. Total diversity is composed of Inherent and Induced Diversity.

Attributes

Edges have attributes or characteristics that influence their effectiveness in producing degrees and amounts of habitat richness which is usually reflected in wildlife species richness. Attributes that have influence in terms of the amount of habitat include edge length, edge width, and configuration (fig. 7).

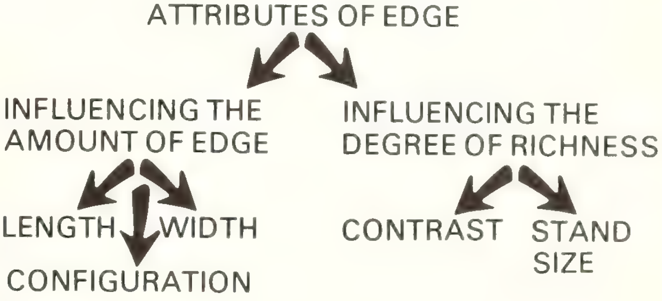
ATTRIBUTES OF EDGE
INFLUENCING THE AMOUNT OF EDGE
INFLUENCING THE DEGREE OF RICHNESS
LENGTH
WIDTH
CONFIGURATION
CONTRAST
STAND SIZE

Figure 7.--Edges have attributes that influence the amount of edge and the richness of that edge.

Influence on Amount of Edge

Edge length is merely a measure of how much edge there is. Edge width is the width of the mix of the two types with an abrupt edge yielding less unique habitat than a wider edge. The combined effect of edge length and width is best visualized as the area (length X width) of unique habitat that results. Configuration is merely the arrangement of the edge, ranging from simple to an involved mosaic (fig. 2).

Influence on Degree of Richness

Attributes that influence the degree of habitat richness include contrast and the relationship of stand size to diversity.

Edge Contrast.--The quality or effectiveness of edges is related to the degree of contrast represented by the edge. For example, the idealized successional stages shown in figure 8A in reality are a continuum and not discretely different; but, for our purposes they are considered discrete. There are six

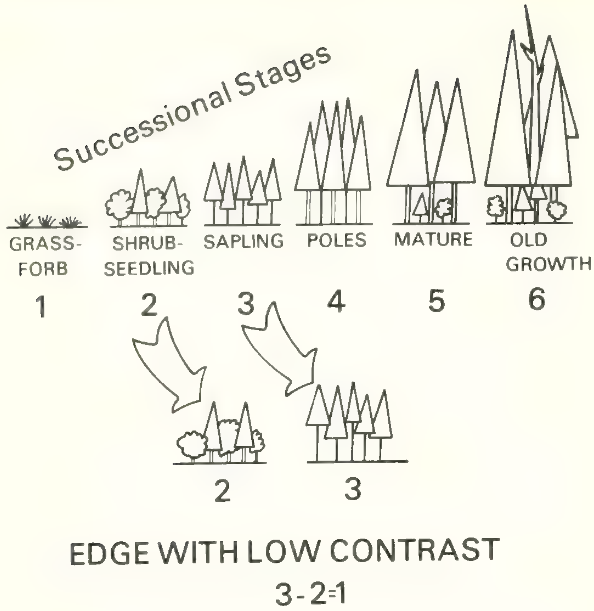

Figure 8a.--Edges differ in their degree of contrast.

successional stages and 15 possible edges between combinations of two types. Each combination will vary in degree of contrast. For example, the grass-forb stages against a sapling stage (fig. 8B) will be less dramatic than the grass-forb stage against old growth. The degree of contrast may be roughly judged by subtracting the numbers (as illustrated) of any two possible combinations of successional stages--the greater the difference in scores the greater the contrast.

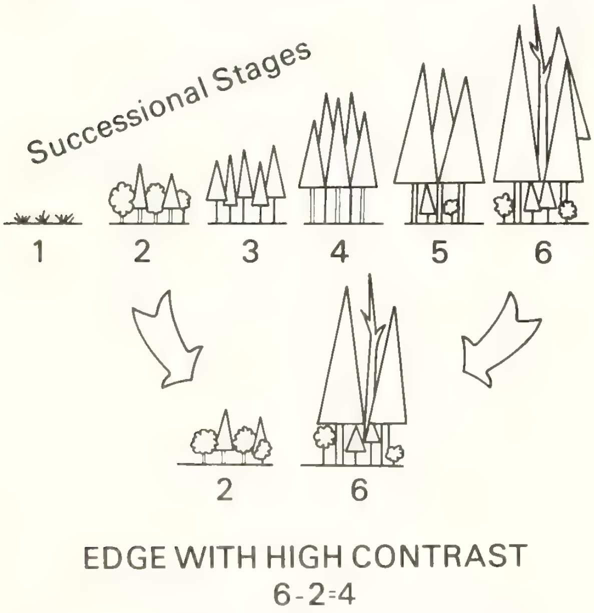

Figure 8b.--Edges differ in their degree of contrast.

The Relationship of Stand Size to Diversity.--Each area has a unique set of possibilities for diversity. One area may have a high degree of diversity resulting from the inherent admixture and arrangement of communities. Such an area may be of low priority or need for increased diversity. Conversely, an area may be of only one community or a few communities and be a good candidate for diversity improvement.

Superficially, it would seem possible to increase diversity indefinitely by making smaller and smaller "islands" or stages thereby making more and more edges. Upon closer scrutiny, it seems more likely that beyond some point the area's increasing heterogeneity would tend toward homogeneity (fig. 9).

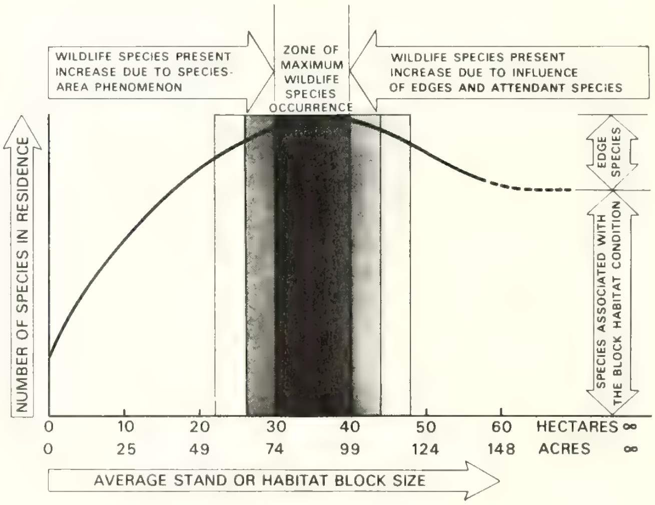

Figure 9.--Habitat diversity is related to the average size of the blocks of habitat. The relationship shown is a generalized one. The curve is generalized.

In other words, the pieces would become so small and so mixed up that the area would assume a sameness. This phenomenon is largely a matter of scale. At what point does increasing diversity tend toward homogeneity and decreasing diversity?

Galli et al. (1976:356) said that "The number of species present in a particular habitat is strongly influenced by the size of that habitat." Number of species of both animals and plants in an area is another indicator of diversity. Arrenhius (1921) and Gleason (1922) seem to have pioneered this concept. The rather voluminous literature on the subject that has developed since that time is well summarized and reviewed by Cain and Castro (1959) and Greig-Smith (1969). Hopkins (1955), Preston (1960), and MacArthur and Wilson (1967) show or discuss species-area curves. After review of this literature, Galli et al. (1976) concluded that there was usually a direct linear relationship between species number and the logarithm of the area and that there were distinct relationships for different areas. This simply means that the number of species occupying an area or type increases with the size of that area--i.e., there will be fewer species in a 0.40-hectare (1-acre) habitat block than in a 20.2-hectare (50-acre) block of identical habitat--and that the absolute numbers will be different on different areas.

The point at which increasing diversity tends to become decreasing diversity is that point where the average size of the habitat blocks becomes smaller than the size required to maximize the number of species present. Galli et al. (1976) studied the relationship between number of bird species present and the size of blocks of forest habitat in agricultural lands in New Jersey. They found (p. 363) that "Bird species richness increases significantly through an island size of 24 hectares (59.28 acres) and is likely to continue increasing significantly at forest sizes beyond 24 hectares." The increase in bird species with size of the habitat was attributed to the occurrence of new species as their minimum habitat size requirements were met, the inclusion of specific habitat components in sufficient quantity, and the requirement for specialized forest-interior conditions.

Study of a 44-hectare (108.68-acre) plot showed a decline of species numbers over the numbers predicted by their best prediction equation of:

$$y = 0.81 + 4.54 X^{.05}$$

where y is species richness and X is forest size or area in hectares. The correlation coefficient (R) was 0.92, accounting for 85 percent of the variation in species richness. Further, the number of species was less than that encountered on the next largest plot (24 hectares or 59.28 acres). The decline was attributed to lack of true edge species.

Data are lacking for these relationships in the Blue Mountains, but a best estimate is required. The assumptions are that bird species richness (at least birds) will increase significantly with habitat size to about 34 hectares (84 acres) and that bird species richness is a reasonable indicator of the relationship of all vertebrate wildlife to habitat size.

So, wildlife species richness should be approaching the maximum where the *average* habitat size is approximately 34 hectares (84 acres). Special attention should be paid to emphasis on the word "average." This would indicate the existence of habitats both larger and smaller than 34 hectares (84 acres). The larger habitats will accommodate the few species that require habitat blocks larger than the average, and smaller habitats will increase edge effect.

EDGE AS A MEASURE OF DIVERSITY

A Feasible Alternative

Both inherent and induced edges are a direct reflection of the variety or diversity present within an area. Patton (1975) has indicated that edge measurement could be used as a "diversity index." Such an index as a rough measure of diversity could be a boon to those required to do large-scale or extensive land use planning or management. The standard diversity indices (Pielou 1975) require far too detailed and expensive measurements of species numbers and frequency to represent a viable alternative for planners and forest managers operating under time pressures and budget and personnel restraints.

The utilization of edges as an indicator or index of diversity is, however, a feasible alternative.

Why Measure Diversity?

Diversity may help insure the continued existence of the living components of the system--plants as well as animals. That goal is laudable enough in itself but it has practical aspects of common sense. In the ecological sense, diversity is thought to be directly related to stability and, as such, is an insurance policy for the system in its ability to withstand disaster. It has been said that the first rule of intelligent tinkering is to save all the pieces. Further, the Chief of the Forest Service said the wildlife goal for National Forests is to insure diversity of wildlife and to maintain or enhance their numbers (USDA Forest Service 1976). If the stated goal is diversity, it behooves us to be able to account for it in our management planning and the products of that planning.

THE DIVERSITY INDEX

Derivation of the Index

Patton (1975) described a system for quantifying habitat edge that expressed, by index, the amount of edge effect within any size area. Because of the relationship between edge and interspersion and because these factors were a measure of diversity, he referred to this measure as the "Diversity Index" (DI).

Patton worked entirely with English measure. The same results are achieved with metric measure.

The following is taken directly from Patton (1975:172, reproduced with permission):

The geometric figure with the greatest area and the least perimeter or edge is a circle. If the ratio of circumference to area of a circle is given an index value of 1, a formula can be derived to compute a comparable index for any area to compare with a circle. Any index larger than 1 is a measure of irregularity and can be used as a DI. A 1-acre circle has a circumference of 739.86 feet and an area of 43,560 square feet. The formula to set the ratio equal to 1 is:

$$\frac{C}{2\sqrt{A \cdot \pi}} = 1$$

where C is the circumference, A is the area, and π is 3.1416. This same formula is often used by limnologists to express shoreline irregularity of a lake. The next step is to restate the formula for habitat diversity as:

$$DI = \frac{TP}{2\sqrt{A \cdot \pi}}$$

where TP is the total perimeter around the area plus any linear edge within the area.

Several examples will show how the DI is computed and what it means. A 1-acre square has 208.71 feet on a side (Fig. 1A) [fig. 10A], *and the perimeter of the block is 834.84 linear feet.*

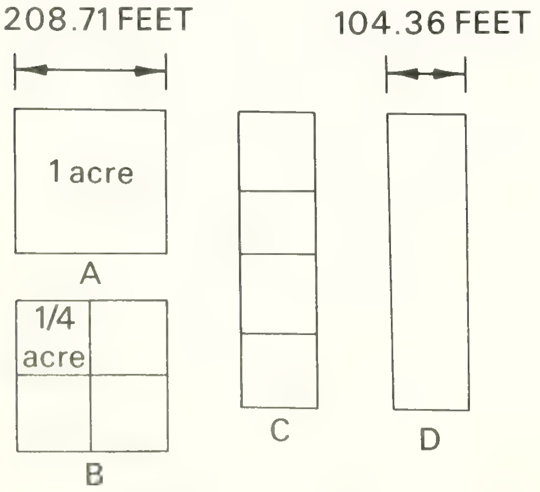

Figure 10.--Comparison of Diversity Indexes: A = 1.13, B = 1.69, C = 1.83, D = 1.41 (after Patton 1975, used with permission).

Substituting these values in the formula:

$$DI = \frac{834.84}{2\sqrt{43560 \times 3.1416}} = 1.13$$

This indicates a square of 1 acre has 0.13 times more edge than a circle of 1 acre. Dividing the 1-acre block into 4 units of different vegetation types increases the DI to 1/69 (Fig. 1B) [fig. 10B]. *If the 1-acre block is divided into 4 blocks in a long, narrow unit (Fig. 1D)* [fig. 10D], *the DI is increased to 1.83.*

In Fig. 1D [fig. 10D], *the TP (1356.68 feet) is computed by adding the outside perimeter (1043.60 feet) to the 3 inside edges (313.08 feet).*

The DI can be expressed as a percentage figure when convenient. It is only necessary to rewrite the formulas as:

$$\text{Percent} = (DI - 1)100$$

For the 1-acre square with a DI of 1.13, the percent is:

$$(1.13 - 1) \times 100 = 13\%$$

This percent figure simply means that the 1-acre square has 13 percent more perimeter than a 1-acre circle. A square-mile block also will have 13 percent more perimeter than a circle of the same area.

Adaptation to Need

Patton's diversity index assumes that the total perimeter of the "area" is edge. In that case, the index is valid. In land use planning, quite likely all or part of the perimeter of an area under consideration will not be an edge in the ecological sense. In that case the index would not be valid.

Further, if diversity is expressed as a product of edge we consider it as derived from two sources (fig. 11).

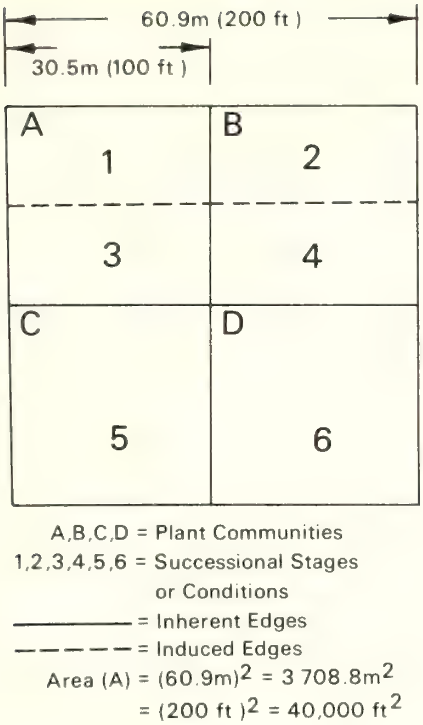
60.9m (200 ft.)
30.5m (100 ft.)
A
B
1
2
3
4
C
D
5
6
A,B,C,D = Plant Communities
1,2,3,4,5,6 = Successional Stages or Conditions
———— = Inherent Edges
– – – – – = Induced Edges
Area (A) = (60.9m)² = 3 708.8m²
= (200 ft.)² = 40,000 ft²

Figure 11.--An area showing plant communities, successional stages, and their attendant edges.

The first source is the inherent edges--those that are site related and result when plant community meets plant community. Such edges may be considered the degree of diversity "given" to the area.

The second source is the induced edges--those that occur when successional stage meets successional stage or condition meets condition within plant communities. These induced edges can be produced when and where desired by management action. Induced edges, however, are certain to result from any action or phenomenon that alters vegetative structure.

Inherent Diversity Index

The inherent diversity index is computed as follows:

$$\text{Inherent DI} = \frac{TE_c}{2\sqrt{A \cdot \pi}}$$

where TE_c is the total plant community to plant community edge in feet or meters found within or on the perimeter of the area under consideration; A is area expressed in square feet or square meters; π is 3.14.

The inherent DI is then expressed as a percentage increase over perfect simplicity by this process:

$$\text{Inherent DI percent} = (\text{inherent DI})100$$

For example, consider figure 11. A 200- x 200-foot square (40,000 square feet) is divided into four equal plant communities or perhaps, timber types. The perimeter of the area is, in this case, also an inherent edge. The inherent DI percent is computed as follows:

In feet

$$\text{Inherent DI} = \frac{TE_c}{2\sqrt{A \cdot \pi}}$$

$$= \frac{1200 \text{ ft.}}{2\sqrt{40{,}000 \text{ ft.}^2 \cdot 3.14}}$$

$$= 1.69$$

In meters

$$\text{Inherent DI} = \frac{TE_c}{2\sqrt{A \cdot \pi}}$$

$$= \frac{366 \text{ m}}{2\sqrt{3708.8 \text{ m}^2 \cdot 3.14}}$$

$$= 1.69$$

$$\text{Inherent DI percent} = (\text{inherent DI})100$$

$$= (1.69)100 = 169\%$$

The number of plant communities represented is also an important component of diversity. Although the number of plant communities will obviously increase the inherent DI percent, it seems appropriate to add a descriptor showing the number of communities (Patton 1975). The descriptor may be added in parenthesis after the inherent DI percent. In this case:

Inherent DI percent (number of communities)
or 169%(4)

Remember that in this example the total perimeter represented inherent edge and was included in calculating TE_c. If all, or any part, of the perimeter had not been inherent edge, those parts would not have been used in computing TE_c. Only the portions of the area perimeter that are inherent edge are used in deriving TE_c. This represents a modification in Patton's (1975) approach described earlier.

Induced Diversity Index

Induced diversity can be expressed in the same manner as follows:

$$\text{induced DI} = \frac{TE_s}{2\sqrt{A \cdot \pi}}\text{; then,}$$

$$\text{induced DI percent} = \text{induced DI}(100);$$

where TE_s is total length, in meters or feet, of successional stage to successional stage (or condition to condition) edge within plant communities or along the periphery or the area under consideration.

Again, consider figure 11. The dotted lines represent induced edge within plant communities A and B. The TE_s is 60.9 meters (200 feet) and, remember, the area (A) is 3708.8 square meters (40,000 square feet). The induced DI percent is computed as follows:

In feet

$$\text{Induced DI} = \frac{TE_s}{2\sqrt{A \cdot \pi}}$$

$$= \frac{200\text{ ft.}}{2\sqrt{40{,}000\text{ ft.}^2 \cdot 3.14}}$$

$$= 0.28$$

In meters

$$\text{Induced DI} = \frac{TE_s}{2\sqrt{A \cdot \pi}}$$

$$= \frac{60.9\text{ m}}{2\sqrt{3708.8\text{ m}^2 \cdot 3.14}}$$

$$= 0.28$$

$$\text{Induced DI percent} = \text{induced DI}(100)$$

$$= 0.28(100) = 28\%$$

The number of successional stages or conditions represented should be added to parentheses after the induced DI percent as a further descriptor of diversity. The example is used to illustrate:

Induced DI percent (number of successional stages or conditions)

28%(6)

Total Diversity Index

Total DI is an index to the combined effects of inherent DI and induced DI. This figure may be computed as follows:

$$\text{total DI} = \frac{TE_{c+s}}{2\sqrt{A \cdot \pi}}\text{; then,}$$

$$\text{total DI percent} = (\text{total DI})100;$$

where TE_{c+s} is the total length, in meters or feet, of all inherent and induced edges. For figure 8, this is computed as follows:

In feet

$$\text{total DI} = \frac{TE_{c+s}}{2\sqrt{A \cdot \pi}}$$

$$= \frac{1400\text{ ft.}}{2\sqrt{40{,}000\text{ ft.}^2 \cdot 3.14}}$$

$$= 1.97$$

In meters

$$\text{total DI} = \frac{TE_{c+s}}{2\sqrt{A \cdot \pi}}$$

$$= \frac{427\text{ m}}{2\sqrt{3708.8\text{ m}^2 \cdot 3.14}}$$

$$= 1.97$$

$$\text{total DI percent} = \text{total DI }(100)$$

$$= 1.97(100) = 197\%$$

Total DI percent can be enhanced by showing the contributions of the number of plant communities and the number of successional stages or conditions as follows:

$$\text{Total DI percent}\left(\begin{array}{c}\text{Number of}\\ \text{communities}\end{array}\right)\left(\begin{array}{c}\text{Number of stages}\\ \text{or conditions,}\end{array}\right)$$

or, in this example:

$$197\%\ (4)\ (6)$$

It should be noted that the expressions of inherent and induced diversity are additive and yield the total diversity expression. This may be expressed as follows:

+	Inherent DI percent Induced DI percent	or	169% 28%
=	Total DI percent		197%

So, if any two of the indices are known, the third may be derived by their appropriate addition or subtraction.

Mapping Codes for Edges

The indices just discussed are valuable in judging the overall status of edge (diversity) within an area of concern. It may be desirable to account for the amount and characteristics of particular edges within a planning area. If so, the following coding is suggested.

Edge type	T = induced; P = inherent
Community(s)	Community to Community for inherent; community for induced
Length	In feet or meters
Width	In feet or meters
Contrast	1 to 5
Configuration	A = abrupt; M = mosaic

So, consider the following code:

P - Pinus ponderosa - 1,700-25-5-A

This means that the area has an edge that is inherent, within the Pinus ponderosa community, 1,700 feet long, 25 feet wide, contrast is 5 and edge is abrupt (A).

UTILIZATION OF THE INDEX IN LAND MANAGEMENT

There are at least three primary uses of the diversity index in land management: (1) the following of trends in habitat diversity on particular management compartments, (2) the evaluation of planned management alternatives in terms of immediate and long-term effects on diversity, and (3) the evaluation of shapes of vegetative treatment blocks such as timber sale units in terms of diversity effects.

Diversity as a goal in management is one that must be used with caution. The degree of diversity of habitat can be evaluated as "good" or "bad" only in relationship to management goals and objectives. For example, maximization of diversity is incompatible with maximization of numbers of particular species. So, diversity is a measure of habitat condition and must be considered in combination with the needs of particular species. A mixture of "management for species richness" and "featured species management" is feasible and probably represents the management that best satisfies the requirement to preclude, to the degree possible, the loss of any species and to insure desired yields of featured species--usually game species or threatened or endangered species (Gill et al. 1976).

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CASE HISTORY of an Excellent White Spruce Cone and Seed Crop in Interior Alaska:

Cone and Seed Production, Germination, and Seedling Survival

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ABSTRACT

Excellent cone and seed years are important for both natural and artificial regeneration. The 1970 white spruce (*Picea glauca* (Moench) Voss) cone and seed crop was the best crop produced by this species since 1958 in interior Alaska. The crop provided an opportunity to make detailed observations of growth and development of cones and seeds, seed dispersal, seed germination, and seedling establishment.

Flowering at lower elevations (135 meters) occurred in late May; but above 600 meters, it occurred 3-5 weeks later. Growth of cones in physical dimensions was essentially completed by early July; however, dry weight increased through August. At 135 meters, seed maturity increased from early July to early August with little change in physical appearance of the endosperm and embryo, and real germination increased from early August to seed fall. Poorly developed seeds (i.e., immature embryos) were observed in collections above 600 meters and north of the Arctic Circle. Seed dispersal at 135 meters occurred 99 days after peak pollination. Total seed fall in undisturbed white spruce stands varied from 250 to 2,000 seeds per square meter; filled seed varied from 38 to 77 percent of total seed fall.

Germination of this seed crop at a study site near Fairbanks began in late May 1971 and exhibited two distinct peaks in activity which were associated with high soil moisture in early summer and midsummer. White spruce seedling mortality was greatest during the first winter when survival was reduced from about 90 to 30 percent. By the end of the fifth growing season, mortality had reduced survival an additional 10 percent. Comparative germination and seedling establishment data are presented for paper birch (*Betula papyrifera* Marsh.).

KEYWORDS: Cone production, seed production, seed crops, seed dispersion, seed quality, regeneration (natural), natural regeneration, regeneration (artificial), artificial regeneration, population dynamics, white spruce, *Picea glauca*, paper birch, *Betula papyrifera*, Alaska (interior), interior Alaska.

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ENGLISH EQUIVALENTS

(9/5°C) + 32 = °F

1 centimeter = 0.39 inch

1 hectare = 2.47 acres

1 kilometer = 0.62 mile

1 square meter = 10.76 square feet

Introduction

Excellent seed years are important for success of both natural and artificial regeneration programs. At northern latitudes these excellent years occur at greater intervals than in southern portions of a species range (Sarvas 1957, Andersson 1965, Waldron 1965, Zasada and Viereck 1970, Chalupka and Giertych 1973). Thus, the occurrence of good cone and seed crops in the north is especially significant as they must provide the majority of seed for reforestation.

Records indicated that the 1970 white spruce (*Picea glauca* (Moench) Voss) cone and seed crop in Alaska was the most productive since 1958 (Zasada and Viereck 1970). From 1970 through 1975, relatively detailed observations were made of cone growth and development, seed maturation and dispersal, seed germination, and seedling establishment in order to assess the regeneration potential of white spruce under subarctic conditions. Cone and seed production were observed in 29 stands in Alaska and a transect along the Richardson Highway (fig. 1, table 1). These observations expand on certain aspects of a more general discussion of white spruce seed production by Nienstaedt and Teich (1972) and provide comparative data for northern white spruce genotypes. Seedlings were observed for the first five growing seasons, generally considered the period of seedling establishment, in a small forest opening located on the Bonanza Creek Experimental Forest near Fairbanks, Alaska.

This study is by no means definitive because annual variation in weather conditions, vitally important to successful regeneration, are not considered. The study was, however, an attempt to provide a relatively detailed case history of the stand establishment phase of white spruce management. We hope this research will help land managers achieve their management objectives and will give forest biologists added insight into the reproductive biology of a species near the northern limits of its range.

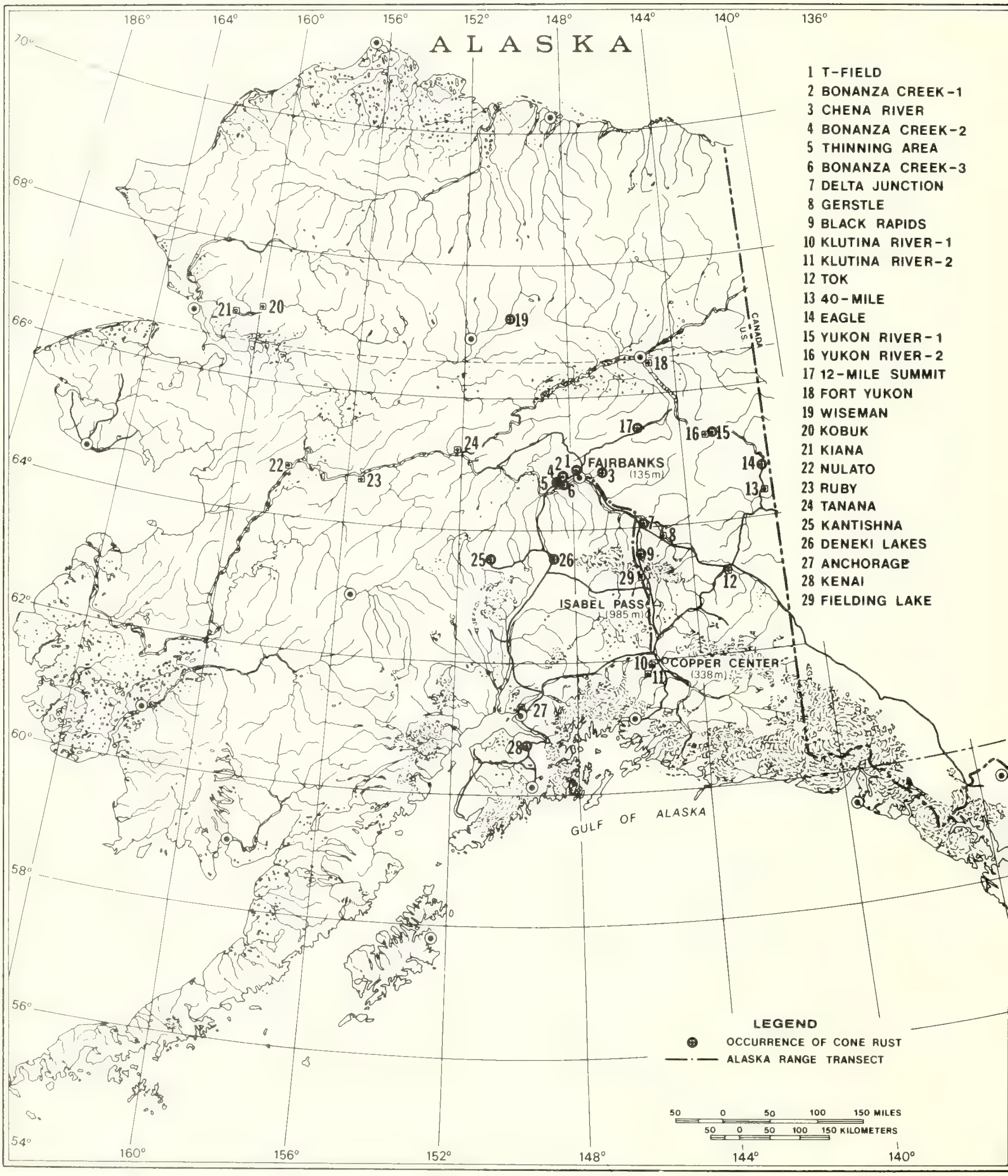

Figure 1.--Location of stands (▣) from which cones and seeds were collected from white spruce in Alaska in 1970.

Table 1--*Latitude, longitude, and elevation of white spruce stands in Alaska from which cones were collected in 1970--and cone length*

Stand number	Area	Latitude	Longitude	Elevation	Observation[1/]	Cone length (mm)	
						$\bar{X}$	Standard error
				Meters			
1	T-field	64°52'	147°50'	170	cd, t, c	40	1.2
2	Bonanza Creek-1	64°45'	148°20'	385	t, c	34	.9
3	Chena River	64°53'	146°43'	200	t, c	36	1.1
4	Bonanza Creek-2	64°44'	148°20'	246	t, c	38	1.3
5	Thinning Area	64°44'	148°20'	230	t, c	36	1.0
6	Bonanza Creek-3	64°44'	148°05'	130	t, c	33	.8
7	Delta Junction	64°10'	145°50'	308	c	33	1.3
8	Gerstle River	63°55'	144°55'	370	c	31	1.0
9	Black Rapids	63°30'	145°50'	708	c	32	1.6
10	Klutina River-1	61°49'	145°32'	492	t, c	32	1.3
11	Klutina River-2	61°53'	145°33'	570	t, c	40	2.5
12	Tok	63°10'	143°10'	615	c	43	1.1
13	40-mile	64°26'	141°21'	523	c	38	1.4
14	Eagle	64°46'	141°12'	338	c	38	1.2
15	Yukon River-1	65°20'	143°05'	215	t, c	39	1.3
16	Yukon River-2	65°20'	143°05'	215	t, c	40	1.4
17	12-mile Summit	65°20'	146°05'	769	c	36	2.2
18	Fort Yukon	66°35'	145°18'	129	c	37	1.1
19	Wiseman	67°25'	150°05'	492	c	37	1.2
20	Kobuk	66°52'	156°50'	46	c	40	1.7
21	Kiana	66°44'	160°25'	30	c	38	1.0
22	Nulato	64°44'	158°05'	33	c	38	1.2
23	Ruby	64°45'	155°30'	62	c	32	2.1
24	Tanana	65°10'	152°05'	65	c	29	1.7
25	Kantishna	63°31'	150°54'	615	c	35	2.0
26	Deneki Lakes	63°37'	148°42'	660	c	37	2.0
27	Anchorage	61°10'	149°40'	69	c	39	1.2
28	Kenai	60°20'	149°30'	308	c	50	1.3
29	Fielding Lake	63°10'	145°35'	892	c	28	.8

[1/] cd = cone development; c = cone collection; t = seed traps and cone counts.

Cone and Seed Production

MALE STROBILI DEVELOPMENT

Methods

Development of male strobili was observed on three trees in stand 1, T-field (fig. 1). Collections were made at 1- to 3-day intervals from May 15 to 27. A final collection was made on June 3 after all pollen had been dispersed. On all collection dates except May 25, 20 strobili were collected from each tree. On May 25, obvious external differences existed between strobili on the same tree, and 20 collections were made from each of the following categories: (1) no open pollen sacs, (2) 50 percent or less of pollen sacs open, and (3) more than 50 percent of pollen sacs open.

Collections were made between 0600 and 0700 hours, placed in plastic bags, brought to the laboratory, and weighed within 1 hour of collection. Pollen loss appeared minimal. Drying was at 65°C for 24 hours.

Pollen density and seasonal periodicity were measured with one recording pollen sampler (Sarvas 1968) in stand 1, T-field (15 m above ground) and two each in stands 2 (Bonanza Creek-1) and 3 (Chena River), 30 m above ground. These heights corresponded with the base of the female cone-producing portion of the trees. Samplers were changed weekly.

Results and Discussion

The first sign of bud expansion was observed several days before collection of the first sample on May 15. By May 15 all male buds were noticeably expanded, and the apical portion of some strobili was visible. Dry weight of the male buds for the three trees ranged from 0.017 to 0.019 gram, and moisture content varied from 322 to 366 percent of dry weight (fig. 2). Increases in dry weight between May 15 and 21 were between 110 percent (tree 1) and 190 percent (tree 3) and moisture content between 190 and 260 percent.

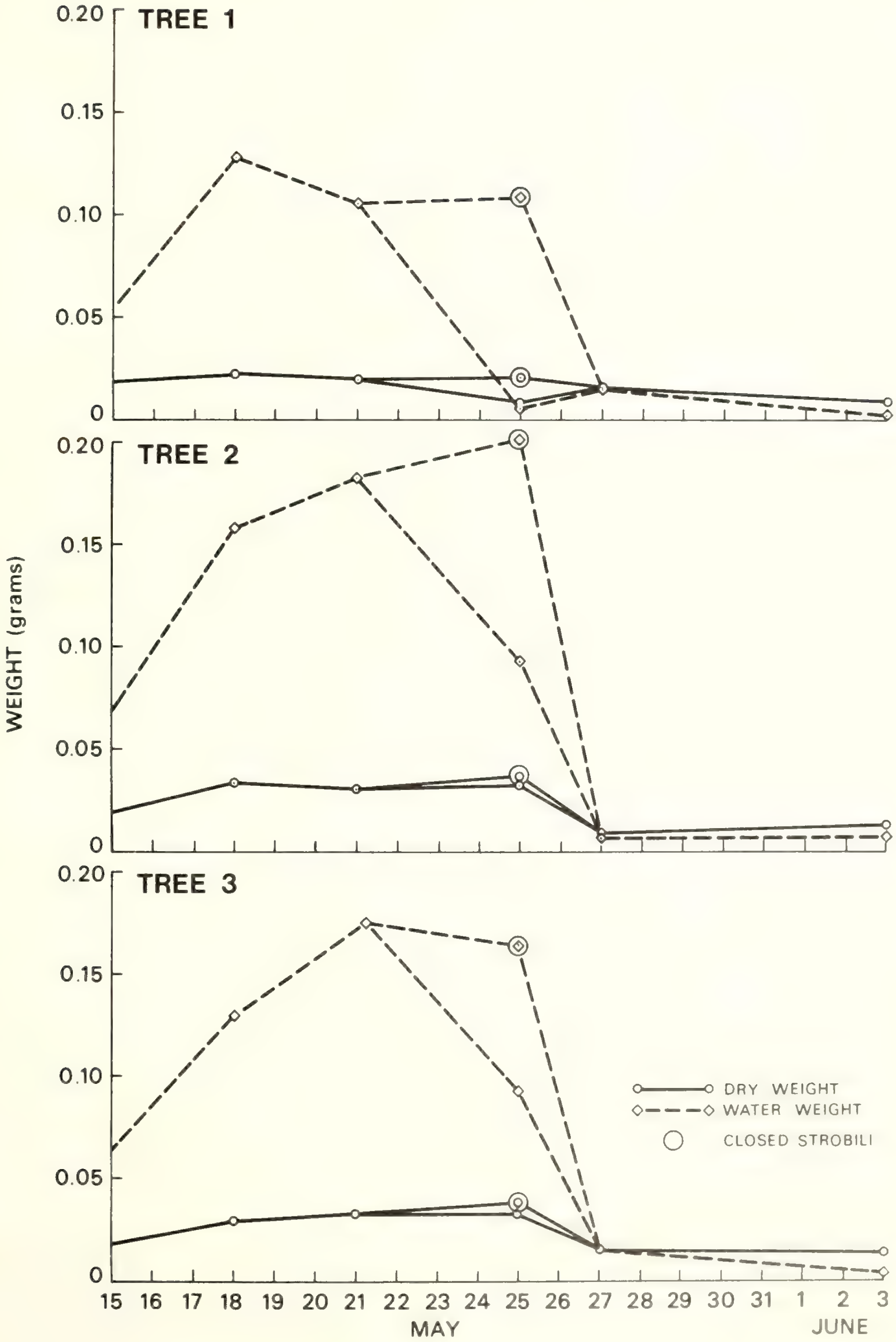

Figure 2.--Seasonal changes in dry weight and water weight of male strobili of white spruce.

Pollen dispersal was first observed on May 22, although maximum dispersal did not occur until May 25. The male cones on an individual tree varied significantly in stage of development on May 25. Differences in developmental stages on the basis of external appearance could not be distinguished before May 25; on May 25 at least three developmental stages were distinguishable. Dry weight and moisture content for these stages for tree 1 were as follows:

	Dry weight (Grams)	Moisture content (Percent)
Unopened	0.02	550
Partially opened (50 percent or less unopened pollen sacs)	.02	200
Fully opened (more than 50 percent of pollen sacs open)	.01	58

The majority of the pollen was shed by May 27 in these three trees. Dry weight of strobili on May 27 varied from 0.01 to 0.02 gram and moisture content from 67 to 102 percent. By June 3 the strobili contained essentially no pollen and moisture content was less than 50 percent.

Pollen dispersal, as measured by the pollen samplers, in stand 1 (T-field) agreed reasonably well with the observations of the developing male strobili through May 27. Only small amounts of pollen were observed on the samplers before May 24. Large quantities of pollen were dispersed from the sample trees on May 25 and 26, coinciding with a large accumulation of pollen on the sampler. From May 28 until about June 6, however, there was little relationship between the amount of pollen remaining in cones on the three sample trees and the quantity of pollen on the sampler (fig. 3).

Several factors contributed to the difference between strobili pollen and sampler pollen:

1. Pollen deposited on branches, needles, and other objects was redistributed by wind.

2. We observed on May 27 that some trees contained numerous unopened male cones, indicating that an undetermined percentage of the trees were less developed than the three sample trees and shed pollen later.

3. Large numbers of black spruce (*Picea mariana* (Mill.) B.S.P.) are within 200 meters of stand 1(T-field). On June 2 we observed black spruce dispersing pollen. The high pollen densities of black spruce which occurred in June probably contributed to pollen counts.

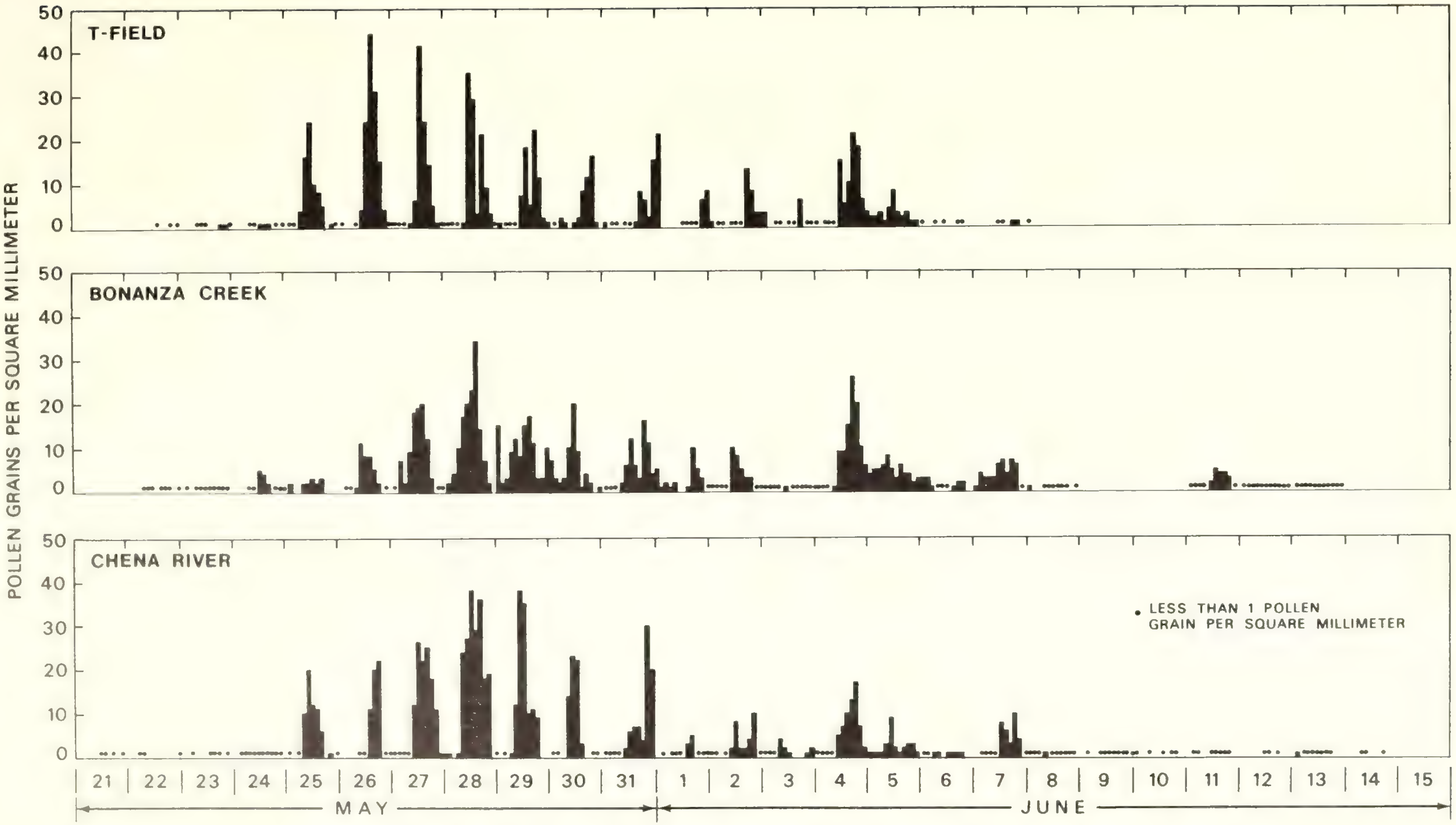

Figure 3.--Seasonal and diurnal course of pollen dispersal in three white spruce stands in Alaska.

4. In other white spruce stands in the vicinity--for example, stands 2 and 3 (Bonanza Creek-1 and Chena River)--peak dispersal did not occur until after May 27, about 2 days after large quantities of pollen were measured in stand 1, T-field (fig. 3).

The following tabulation shows the total amount of spruce pollen collected in each stand while the samplers were in place and while the female cones were receptive;

		Pollen grains per square millimeter	
Stand number and area	Pollination	During period of pollination	Total (through June 15)
1, T-field	May 25 to May 30	510	690
2, Bonanza Creek-1	May 25 to May 30	668	824
3, Chena River	May 26 to June 1	513	741

Winton (1964) reported that anthesis varied from about May 12 to June 1 for white spruce in north-central Minnesota (about 48°N. latitude). Pollen dispersal in the vicinity of Fairbanks has not been observed earlier than mid-May nor later than June 10 (Zasada and Gregory 1969).

Additional observations of variation in timing of pollen dispersal were made along the Richardson Highway on June 26, 1970. This transect started at Fairbanks (elevation, 135 m) and passed through Isabel Pass in the Alaska Range (elevation, 985 m) to Copper Center (elevation, 338 m) (fig. 1).

Pollen dispersal was completed at both ends of the transect. At the lowest elevation (Fairbanks), however, development of female cones was more advanced than at Copper Center. At about 615 m, some pollen still remained in the male cones. At 770-920 m, pollen dispersal was commencing. In the scattered trees above 920 m, reproductive buds were just beginning to break (fig. 4). Male cone development at elevations of approximately 600 m or more in the Alaska Range appeared to be 3 to 5 weeks behind that in the Fairbanks area.

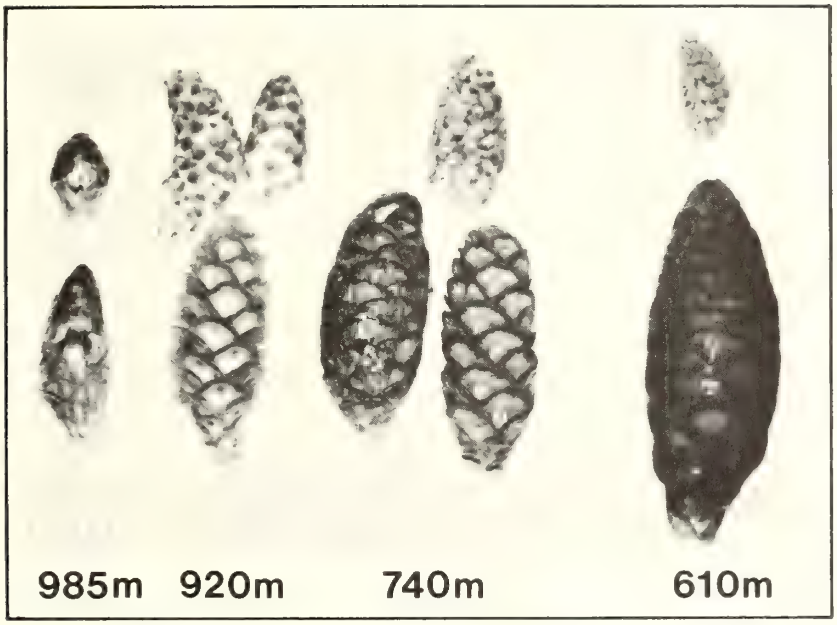

Figure 4.--Variation in male and female cone development on a transect made through the Alaska Range on June 26, 1970.

Strong diurnal patterns of pollen dispersal were observed (fig. 3). The general pattern was characterized by the dispersal of large amounts of pollen between 1000 and 1600 hours. Pollen dispersal was at a minimum between 2000 hours one day and 0400 hours the next day. This dispersal follows the humidity-temperature pattern; that is, peak dispersal at times of highest temperature and low humidity, and minimum dispersal at low temperature and high humidity. Exceptions to this general rule are common and are probably related to the occurrence of rain showers or to delays in normal daily warming.

FEMALE CONE DEVELOPMENT

White spruce cones are initiated the year prior to seed formation (Eis 1967a). Two factors frequently reported as important for reproductive bud formation are the climatic conditions at the time of differentiation and the cone crops of preceding years.

The climatic factors most closely associated with differentiation of large numbers of reproductive buds are above average temperatures and below normal precipitation (Fraser 1958, Matthews 1963). The temperature and precipitation during June 1969 fulfilled these requirements (table 2). Average daily maximum temperatures for four 5-day periods beginning June 11 were 7°C above normal; minimum temperatures were 2°C above normal. Precipitation for June was 70 percent

Table 2--*Average maximum and minimum temperatures and precipitation for 1946-61,*[1] *1969, and 1970*

Month and days	Maximum temperature			Minimum temperature			Precipitation		
	1946-61	1969	1970	1946-61	1969	1970	1946-61	1969	1970
	- - - - - - - -	- - - -	- - - - °C	- - - -	- - - -	- - - -		Centimeters	
May:									
1-5	11.1	14.4	10.7	-2.2	-4.5	-2.6	0.03	0	0.05
6-10	13.9	14.7	15.9	-.6	2.0	1.2	.06	.09	.06
11-15	14.4	12.0	19.3	0	.4	1.6	.08	.40	0
16-20	17.9	18.5	18.6	2.2	2.7	1.0	.12	0	0
21-25	18.3	22.7	20.0	3.9	5.0	4.9	.20	.03	.88
26-31	18.9	17.6	20.0	4.4	1.7	3.6	.32	0	.42
June:									
1-5	21.1	19.7	20.1	5.0	2.5	2.8	.30	.36	.18
6-10	22.8	23.7	18.8	7.2	8.1	.9	.33	0	.14
11-15	21.1	29.0	18.2	6.7	10.9	5.4	.86	0	.14
16-20	22.8	29.4	21.0	7.8	9.2	5.9	.56	0	.06
21-25	21.1	30.6	22.1	7.8	10.5	7.3	1.19	0	1.21
26-30	22.2	28.0	20.7	8.3	9.1	8.2	.86	.50	1.02
July:									
1-5	22.2	22.2	23.8	8.3	8.9	10.9	1.22	.30	.12
6-10	22.8	22.8	20.7	8.3	10.0	7.4	.46	.15	.24
11-15	24.4	24.4	21.2	8.9	11.1	8.1	.76	.20	.15
16-20	22.8	22.8	20.0	9.4	10.0	8.8	1.14	2.56	.49
21-25	22.8	17.2	25.0	8.3	8.5	9.2	1.47	.99	0
26-31	15.0	14.4	23.5	8.9	6.1	9.5	1.30	.58	.24
August:									
1-5	20.0	19.4	18.6	7.2	10.3	8.0	.66	1.25	.60
6-10	21.1	12.1	19.2	7.2	1.7	5.7	1.07	.95	.32
11-15	15.0	13.7	22.2	7.2	-1.6	9.6	.74	0	.10
16-20	20.0	16.2	19.9	6.1	.9	7.1	.53	.03	.01
21-25	18.3	17.1	15.4	5.6	1.3	5.3	1.32	.27	.38
26-31	16.7	18.3	19.2	4.4	3.0	6.3	1.24	.02	.77

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[1] Funsch (1964).

below the average for 1946-61 (Funsch 1964). Average maximum temperatures for July 1969 were equal to or lower than the long-term average; minimum temperatures were both higher and lower.

Cone crops from 1967 to 1969 varied from failures to good crops. The last excellent cone crop and seed year occurred in 1958 (Zasada and Viereck 1970). The 1969 cone crop was fair to good in some stands and a near failure in others. A frost in late May 1969 caused 50-percent or more cone mortality above elevations of about 200 m in the area immediately adjacent to Fairbanks (Zasada 1971).

In summary, the history of cone crops of preceding years and the climatic conditions in the early summer of 1969 met criteria believed optimum for differentiation of a large number of reproductive buds.

Methods

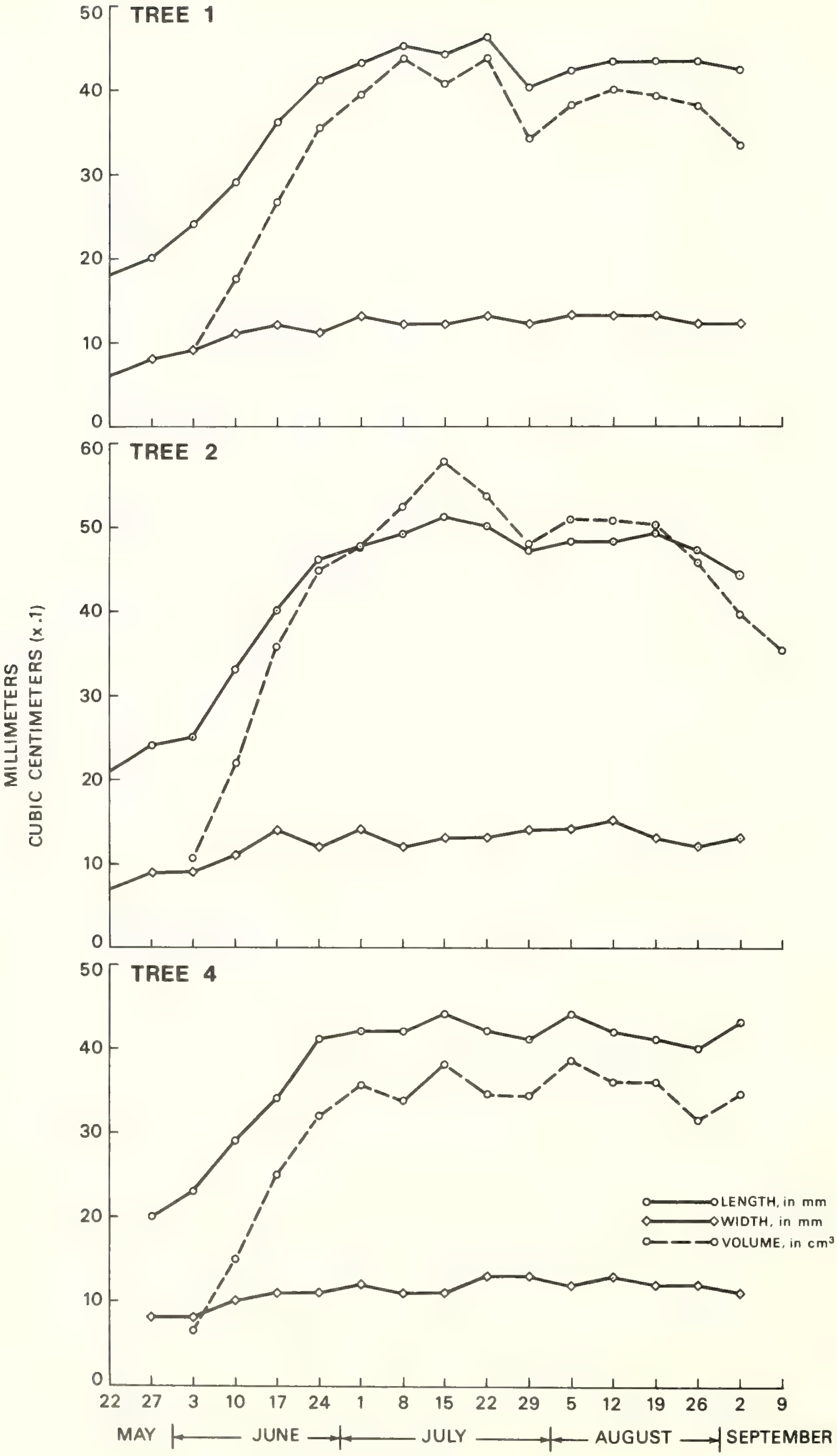
Female cones were collected from five dominant trees in stand 1, T-field, at weekly intervals from bud break until after seed fall began in September. These trees were growing in the same stand as those used in an earlier study (Zasada 1973). Sixteen cones were collected in each sample until July 8, and 30 cones thereafter. Trees were climbed, and each sample consisted of cones collected from different portions of the crown. Cone length was measured and volume determined by water displacement within 1-2 hours after collection. The cones were dried at 65°C until weight change was negligible. Dry weight was determined after cones were cooled in a desiccator.

Results and Discussion

By May 22, female cones were similar to those shown in the least developed cones in figure 4. All cones were fully exposed and cone scales fully opened by May 27. Scales on all cones had closed by June 1.

Growth of cones in physical dimensions (length, width, and volume) occurred primarily before July 1. Increases in cone volume were about 450 to 600 percent of initial values; 200 to 250 percent for cone length; 130 to 200 percent for cone width. Cone volume decreased slightly during the last four sampling periods (fig. 5).

The collection of cones from different areas of the State for the seed quality study provided an opportunity to examine variation in cone length over a large part of Alaska (table 1). Average cone length for these 29 stands varied from 28 to 50 mm. The largest cones were collected on the


TREE 1
TREE 2
TREE 4
50
40
30
20
10
0
60
50
40
30
20
10
0
50
40
30
20
10
0
MILLIMETERS
CUBIC CENTIMETERS (x.1)
LENGTH, in mm
WIDTH, in mm
VOLUME, in cm³
22
27
3
10
17
24
1
8
15
22
29
5
12
19
26
2
9
MAY
JUNE
JULY
AUGUST
SEPTEMBER

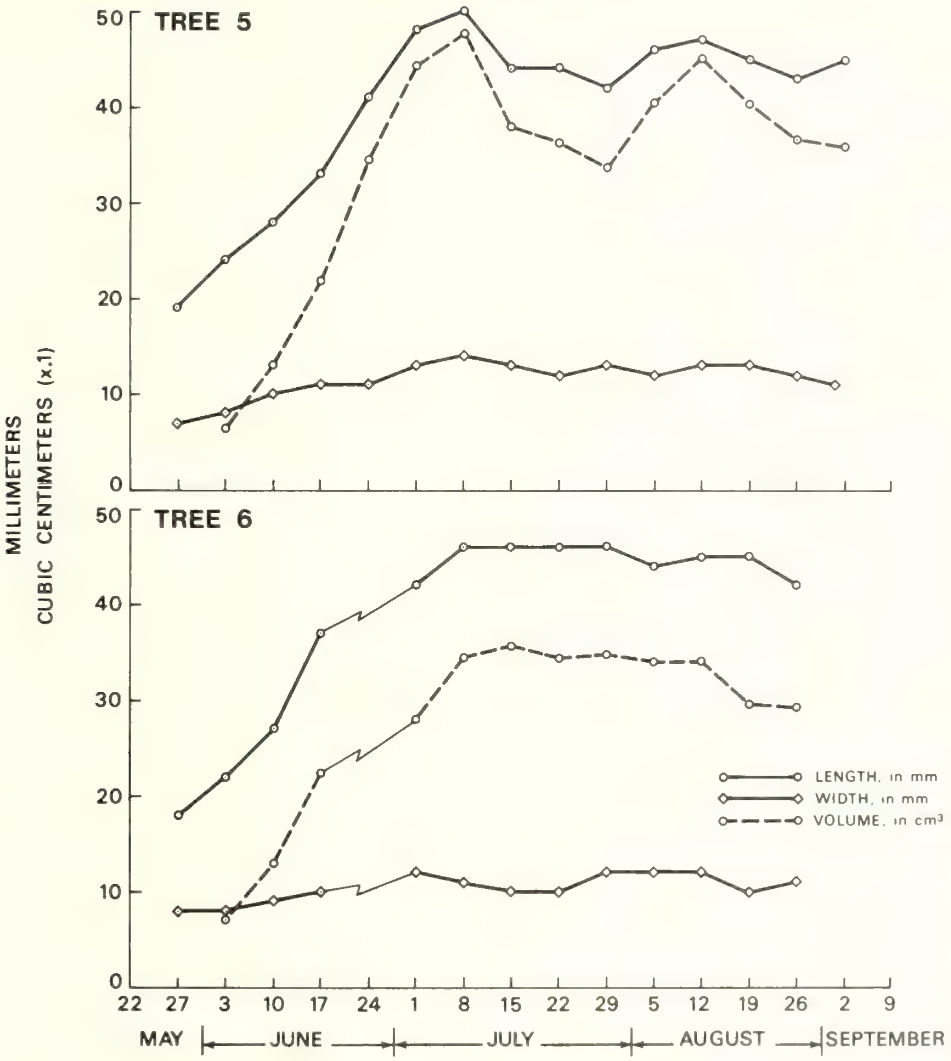


Figure 5.--Changes in volume, length, and width of white spruce cones during the 1970 growing season in Alaska.

Kenai Peninsula (stand 28), where Lutz spruce (*Picea Xlutzii* Little), the natural hybrid between white and Sitka spruce *Picea sitchensis* (Bong.) Carr.), occurs. The smallest cones were found in both low elevation (stand 18, Fort Yukon) and high elevation (stand 29, Fielding Lake) stands.

The same pattern of variation may not exist from year to year. For example, figure 6 shows differences in the length of 1970 cones and those produced before 1970 for the 12-mile Summit stand (stand 17). The differences shown here may be extreme; examples of this magnitude, however, were observed in other stands.

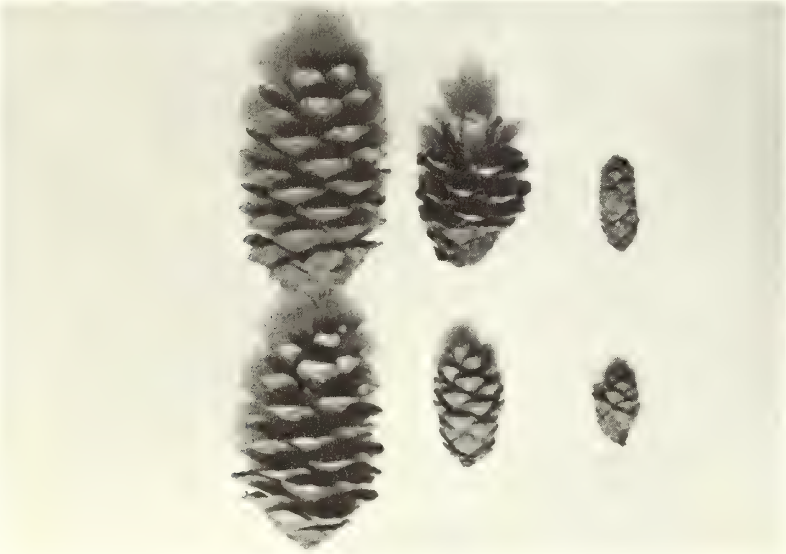


Figure 6.--Annual variation in size of cones from one tree. The two large cones on the left were formed before 1970, and the four smaller cones were produced in 1970 (collected in stand 17, 12-mile Summit).

The effect of environmental factors on cone elongation is probably similar to the effect on white spruce vegetative shoot elongation (determinate growth). One factor generally not considered in more southern coniferous forests which must be considered in these northern forests is that the cones of higher elevation stands in this study may have had their growth limited by the length of the growing season as well as by factors prevailing during the period when cones are actually expanding. As mentioned earlier, cone development in higher elevation stands (above 600 m) was at least 3 to 5 weeks behind that at 125 to 155 m.

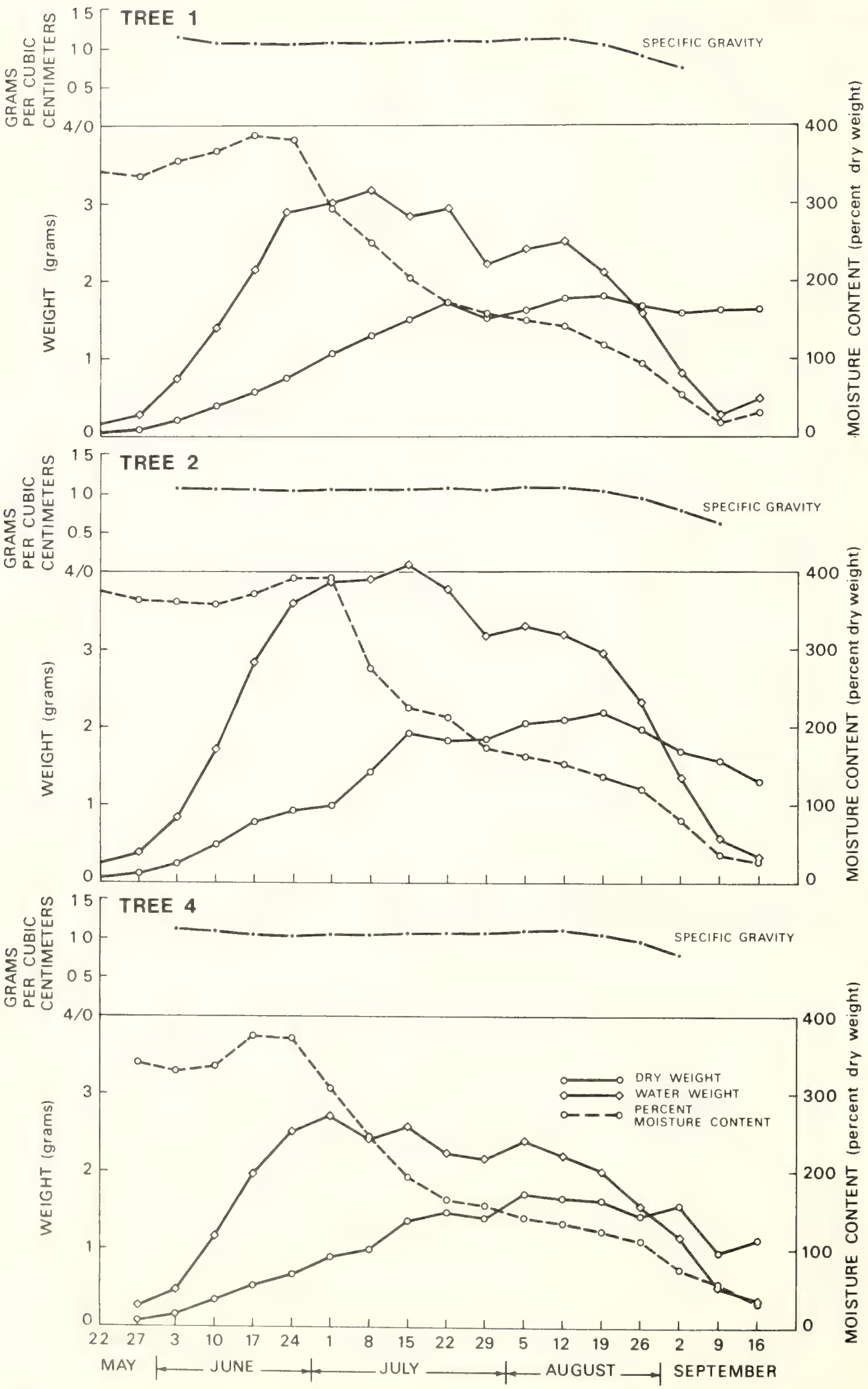
Seasonal patterns of changes in dry weight differed from those for water weight and percent moisture content. Dry weight increased gradually through late July or early August and then appeared to decrease during the several weeks prior to seed dispersal. Cone water content increased rapidly through early July, a pattern similar to that of changes observed in physical dimensions. After early July, water weight decreased until seed dispersal began; at this time water weight was similar to that of the young cones in late May (fig. 7).

Cone moisture content (percent of dry weight) was highest during June; it ranged from 300 to 400 percent. Clausen and Kozlowski (1965) reported a maximum moisture content of about 400 percent in late May and early June for white spruce in north-central Wisconsin. Beginning in early July, percent moisture content decreased. This decline was relatively rapid through mid-July. From mid-July to mid-August, moisture content decreased more slowly; rate of decrease accelerated from mid-August to seed fall. On September 2, shortly after seed dispersal began, percent moisture varied from 25 to 80 percent (fig. 7).

Changes in percent moisture content (dry weight basis) were not always associated with changes in cone water content (in grams). This was particularly noticeable during late June and early July, when percent moisture content began to decrease rapidly; at this time the cone water content was either increasing or relatively stable. Decrease in percent moisture at this time was associated with increasing dry weight of cones. This has been observed by Clausen and Kozlowski (1965) for white spruce, black spruce, larch (*Larix laricina* (Du Roi) K. Koch) and eastern hemlock (*Tsuga canadensis* (L.) Carr.). Changes in percent moisture were more closely associated with decreasing water weight after mid-August (fig. 7).

The relationship between cone development and seed development is the most important consideration from a practical standpoint. Three stages of seed development, are prefertilization, embryo enlargement, and the period between attainment of maximum embryo size and seed dispersal. Based on work by Rauter and Farrar (1969) indicating that fertilization in white spruce occurs about 3 weeks after pollination and on work by Fechner (1974) who reported that fertilization in blue spruce occurred 1 week after cones became pendent, we think the prefertilization period ended between June 17 and 24. Cones on trees in stand 1, T-field, become pendent about June 17. Embryo growth was completed by August 5 (Zasada 1973); seed dispersal began between September 2 and 10. When we compare these dates with the dates in figures 5 and 7 we see that, with the exception of cone dry weight, 90 percent or more of the cone growth occurred during or shortly after the prefertilization stage. There is little direct correlation between the attainment of seed maturity and changes in cone physical dimensions. The relationships which do occur appear to be between the attainment of critical levels of specific gravity and moisture content and seed maturation.

Crossley (1953) concluded that the most reliable indices of seed maturity in white spruce were cone firmness, seed coat color, and seed brittleness. Cone firmness was defined by Crossley as any degree of flexibility when the cone is squeezed between the thumb and finger. This criterion was met by the August 12 samples taken for this study. Changes


TREE 1
TREE 2
TREE 4
SPECIFIC GRAVITY
GRAMS PER CUBIC CENTIMETERS
1.5
1.0
0.5
4/0
3
2
1
0
WEIGHT (grams)
MOISTURE CONTENT (percent dry weight)
400
300
200
100
0
DRY WEIGHT
WATER WEIGHT
PERCENT MOISTURE CONTENT
22
27
3
10
17
24
1
8
15
22
29
5
12
19
26
2
9
16
MAY
JUNE
JULY
AUGUST
SEPTEMBER

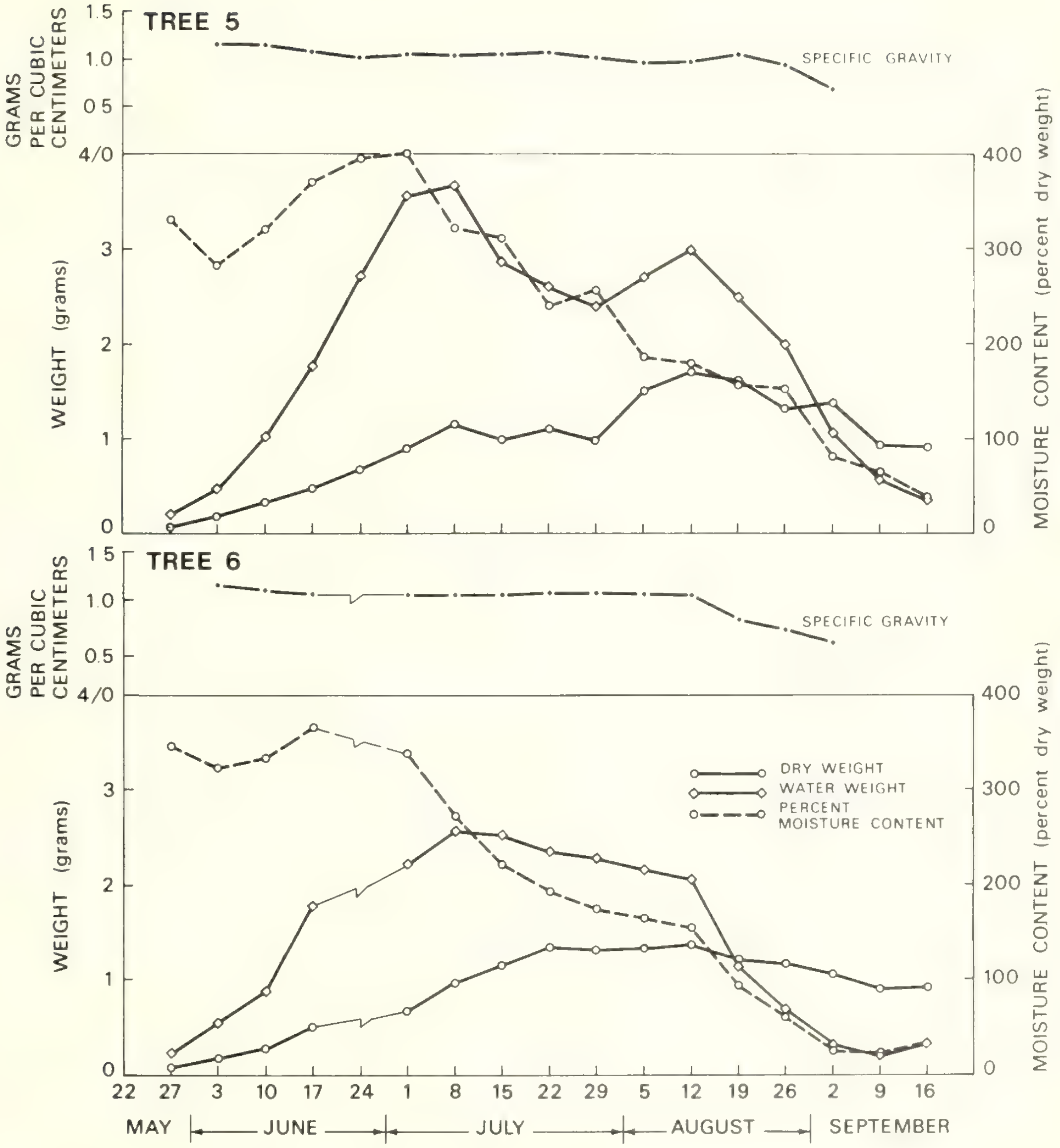


Figure 7.--Changes in dry weight, water weight, percent moisture content (dry weight basis), and specific gravity of white spruce cones from various trees during the 1970 growing season.

in seed coat color to dark brown or black and seed brittleness (seeds snap in two when cut with a sharp blade on firm surface), as defined by Crossley, also occurred on August 12.

In addition to normal cones, three abnormal cone types were observed. The most common was the bisexual cone. Cones with the female portion located at the apex were most common; only one out of many hundreds of these cones had the male portion at the apex. This abnormality was observed to a minor extent in many trees and was abundant in tree 5 in stand 1, T-field. Proliferated and forked cones were less common abnormalities (fig. 8). These cone types were reported in other North American conifers (Bingham et al. 1969, Edwards 1971).

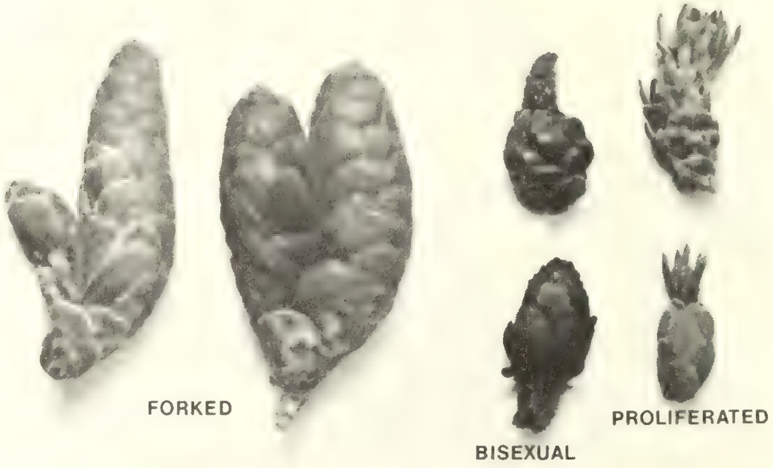


Figure 8.--Abnormal cones produced by white spruce in 1970 in Alaska.

Changes in color are an interesting aspect of white spruce cone development. White spruce cones may be green, pink, red, or a combination of these colors. The colors are most distinctive shortly after bud break. Cones enclosed in kraft bags to prevent pollination on a "red-coned" tree remained green. About 1 week after removal of the bag, the cones became the color of the rest of the cones on the tree, indicating a light-sensitive reaction. Teich (1970) suggested that color of female flowers in white spruce is controlled by a single gene.

The effects of insects on development were not assessed. Werner (1964) reported on white spruce cone and seed insects in Alaska.

Inland spruce cone rust (*Chrysomyxa pirolata*) was commonly observed in cones collected throughout the State in 1970. Areas from which rust could be identified are shown in figure 1. Nelson and Krebill (1970) reported that this disease interferes with seed dispersal and lowers the viability of the seed. Ziller (1974) provides specific details concerning this disease.

SEED MATURITY

Seed maturation in arctic and subarctic forests of northern Europe and Russia is known to be limited by adverse weather conditions during the growing season (Gustafsson and Simak 1958, Norin 1958, Andersson 1965). No detailed studies on this subject have been reported in North America. This study was not designed to test this hypothesis for white spruce, but observations indicated that seed did not mature at certain locations in 1970.

Two general types of immaturity can be recognized. The most obvious immaturity occurs when female gametophyte and embryo are not fully developed at the macroscopic level; the female gametophytic tissue does not completely fill the seed or the embryo does not fill the embryo cavity or is otherwise deficient (for example, poorly developed cotyledons). The second general type of immaturity is biochemical; the development of the female gametophyte and embryo appears normal but the biochemical composition is not complete. In the observations described in the following discussion, only the first type of immaturity is quantified.

Methods

Seed ripening.--Cones collected in conjunction with those used for developmental observations were stored in sealed paper bags at room temperature (20°-22°C). Seeds were extracted and germination tests conducted in early September. Tests were conducted on stratified and unstratified seeds at 25°C with an 18-hour photoperiod for 30 days at a light intensity of 500 foot-candles. The tests were conducted on perlite in plastic boxes. Germination counts were made at 3- to 5-day intervals. A seed was considered germinated when the radicle had penetrated the perlite and the seed coat was raised off the seed bed. Seedlings were allowed to develop for the entire period of the test. After the tests were terminated, the ungerminated seeds were cut open to determine the percentage of filled seed.

Seed quality.--The white spruce stands from which seed was collected can best be described as mature stands which appeared to be representative of this forest type for a given area. No detailed stand descriptions were made. Cones were collected from at least four dominant trees in each of 29 stands (fig. 1). To obtain samples, trees were climbed or branch samples shot from the crowns. At least 20 cones from each tree were measured to the nearest millimeter. Prior to final drying and seed extraction, cones were stored outside and protected from rain, a practice shown to improve germination of seed from immature cones (Zasada 1973). All collections were made within 2 weeks of seed dispersal at Fairbanks.

Final drying was at 20°-25°C for 2 weeks. Seeds were stored in sealed polyethylene bags at 1°-3°C for 1 year prior to germination testing. Seed weights were taken at the time of testing. Germination tests were conducted on four 100-seed replications from each seed lot for each of four trees for 30 days. At the end of the test period seeds were classified as follows:

1. Germinant with normal radicle and hypocotyl development, seed coat lifted off substrate. The majority of these had fully expanded cotyledons.
2. Germinant with radicle development but seed coat not lifted from substrate. Radicle was one to four times seed length.
3. Seed coat split and radicle less than length of seed.
4. Filled, inactive seed. These seeds had endosperm and embryo which appeared normal in cross-sectional view.
5. Filled but seed contents not normally developed. In many cases the endosperm and embryo had a mushy consistency.
6. Empty seeds.

Results and Discussion

Seed maturity in stand 1, (T-field), as indicated by changes in real germination of air-dried seeds collected at weekly intervals, increased from July 8 until early August (table 3). The attainment of relatively constant and high levels of germination preceded large decreases in cone water weight and specific gravity by 1 week or more.

The effect of stratification on germination of seeds at different stages of maturity can be summarized as follows. In 42 percent of the tests conducted before August 5, stratification increased germination. In the remaining cases, 50 percent (29 percent of total) showed decreases in germination due to stratification and the others were not affected. On August 5 and 12 germination of seed from these trees was significantly increased by stratification in only one case. In the August 19 and 26 and September 2 collections, differences between stratified and unstratified seed were from 1 to 7 percent (table 3).

Major changes occurred in endosperm and embryo appearance between early July and early August. After August 5, there appeared to be little change at the x-radiograph level of resolution (fig. 9). A quantitative assessment of embryo growth (that is, elongation of embryo) indicated that enlargement ceased by August 5 (Zasada 1973). Rauter and Farrar (1969) reported that once the embryo ceased growth there were no further changes in anatomical structure.

Table 3--*Germination of stratified and unstratified white spruce seeds collected at weekly intervals in 1970*

Collection date and treatment	Tree 2	Tree 4	Tree 5	Tree 6
		Percent		
July 8:				
Stratified	0	0	0	6.6
Unstratified	0	0	0	14.6
July 15:				
Stratified	29.7	29.7	0	4.8
Unstratified	16.0	0	8.0	5.7
July 22:				
Stratified	44.8	54.0	18.2	60.6
Unstratified	23.0	34.3	47.5	35.9
July 29:				
Stratified	87.8	47.0	73.8	41.3
Unstratified	76.7	70.9	63.1	45.1
August 5:				
Stratified	94.4	83.3	86.9	70.5
Unstratified	93.4	86.4	88.9	89.7
August 12:				
Stratified	96.1	93.0	91.1	87.6
Unstratified	82.2	93.3	97.3	90.6
August 19:				
Stratified	98.5	94.6	94.7	89.7
Unstratified	91.6	91.2	90.8	90.6
August 26:				
Stratified	96.5	95.7	92.0	80.2
Unstratified	97.0	92.4	95.8	85.7
September 2:				
Stratified	95.2	91.3	90.7	--
Unstratified	97.6	90.9	96.3	--

Changes at the microscopic and biochemical levels were not examined; the results of a separate study (Zasada 1973), however, indicated significant changes. In this study, real germination of seeds dried at 40°C for 2 weeks was less than that of air-dried seeds until September 2 (seed fall began less than 1 week later). Although the stress created by the 40°C treatment was relatively severe, the results did show that the closer the collection date was to seed fall the better the seed could withstand the stress.

Phenological observations in the Alaska Range transect, germination testing, seed dissection, and x-radiography

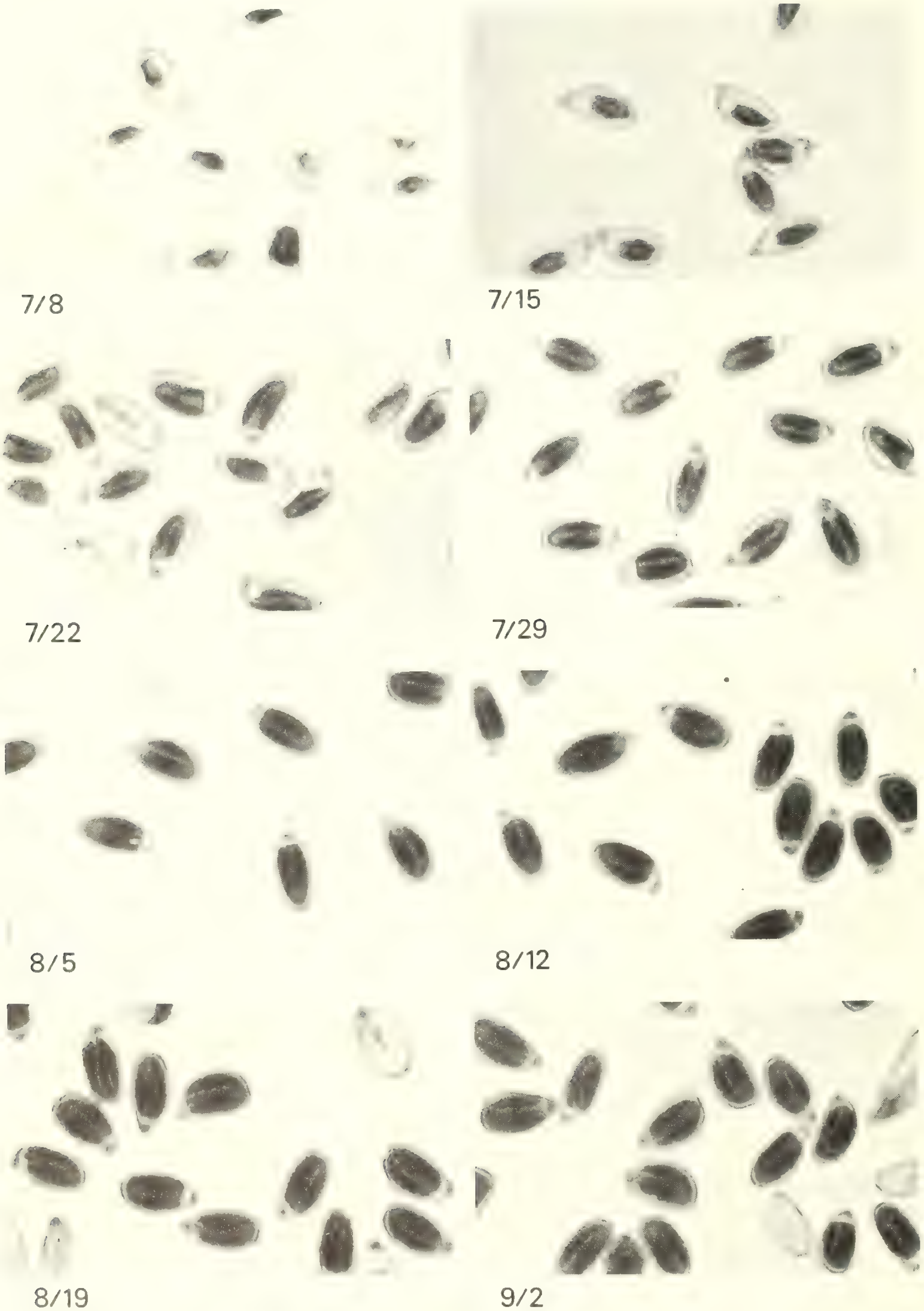


Figure 9.--Endosperm condition, as indicated by x-radiography, in air-dried seeds of white spruce collected at weekly intervals. Radiograph for August 26 is not included as development was same as September 2.

provided further information on seed maturity. Phenological observations indicated that flowering was delayed by as much as 5 weeks at higher elevations. Although this much delay is observed in other mountainous regions, it becomes particularly critical in interior Alaska where growing seasons are normally 90 to 100 days or less. Stands in which phenology was most delayed did not produce mature seed.

The germination and cutting tests indicated a wide range of variation in germinability and seed quality within and between stands (tables 4 and 5). The highest germination (80 percent or higher) occurred in three stands--stand 1 (T-field), stand 4 (Bonanza Creek-2), and stand 5 (Thinning Area)--in the Fairbanks area and in one--stand 15 (Yukon River-1)--on the Yukon River east of Fairbanks. Use of germinability as an indication of seed quality was complicated by the occurrence, in the majority of seed lots, of large numbers of seed which either had split seed coats or were filled but showed no sign of activity.

Although stratification is not recommended for testing white spruce seed (International Seed Testing Association 1966), Wang (1974) has reported that dormancy in white spruce seed may vary with seed source and that prechilling from 21 to 28 days resulted in maximum laboratory germination and superior nursery germination and seedling survival. In tests of five seed lots conducted in 1974, stratification produced a threefold increase in germination in the lots from the Black Rapids (stand 9) and Delta Junction (stand 7) stands but had no measurable effect on the lots from Bonanza Creek-3 (stand 6) and Chena River (stand 3) (table 6). In addition, stratification improved germination in some of the immature seed collected in stand 1 (T-field) (table 3).

Because of the results of the stratification tests and because the endosperm and embryos of imbibed seeds (30 days at germination temperature) were usually adequate to be classified as filled seed, 100 or more filled unimbibed seeds from 18 of the 29 seed lots were dissected. Embryos and endosperm were classified according to criteria of Simak (1957). Of the 17 lots examined, 6 contained a large percentage of seeds with immature embryos and/or poorly developed endosperm (table 5). The embryos which filled the embryo cavities in these six collections (class IV) had poorly developed cotyledons. Of these stands, four were located at 615 m or higher in the Alaska Range, one at 770 m in the White Mountains, and two north of the Arctic Circle. Lower elevation stands with real germination of less than 40 percent had seed with fully developed embryos and endosperms (tables 4 and 5). These data, plus data on the effect of stratification, indicated that biochemical immaturity may occur in some seed lots. From these findings, we recommend that, until the white spruce dormancy pattern is understood in more detail, all lots of white spruce seed from Alaska should be subjected to stratified and unstratified germination tests prior to sowing.

Table 4--*Germination of Alaskan white spruce seed from 1970 seed crop*[1]

Stand number	Area	Germination	Radicle 4 times seed length	Split seed	Filled, inactive seed	Empty seed[4]
				Percent		
1	T-field	85.0 ± 2.8[3]	5.4 ± 4.0	8.4 ± 2.8	1.2 ± 1.2	7.5 ± 4.9
2	Bonanza Creek-1	67.9 ± 10.3	3.0 ± 2.1	16.7 ± 7.4	12.4 ± 13.6	7.2 ± 4.2
3	Chena River	61.7 ± 22.6	3.6 ± .8	27.0 ± 20.8	7.7 ± 4.2	9.0 ± 5.1
4	Bonanza Creek-2	85.0 ± 10.9	2.5 ± 2.4	5.8 ± 3.4	6.7 ± 6.8	2.0 ± 1.6
5	Thinning Area	81.4 ± 13.4	3.4 ± 1.9	11.8 ± 10.5	3.4 ± 2.0	12.5 ± 4.6
6	Bonanza Creek-3	64.8 ± 14.0	7.2 ± 2.4	15.9 ± 8.7	12.1 ± 7.8	14.5 ± 3.9
7	Delta Junction	33.7 ± 20.1	4.9 ± 1.9	42.5 ± 18.2	18.9 ± 17.4	11.2 ± 5.3
8	Gerstle River	67.6 ± 14.7	9.8 ± 2.5	19.5 ± 10.9	3.1 ± 2.4	2.0 ± 1.1
9	Black Rapids	24.4 ± 11.1	8.4 ± 2.2	40.3 ± 11.8	26.9 ± 14.6	13.0 ± 8.7
10	Klutina River-1	26.8 ± 7.7	6.5 ± 4.2	41.1 ± 22.3	25.6 ± 12.9	2.2 ± .6
11	Klutina River-2	12.4 ± 11.3	5.2 ± 2.0	44.2 ± 12.0	38.2 ± 15.2	14.2 ± 9.8
12	Tok	24.9 ± 18.5	6.3 ± 3.2	39.1 ± 8.8	29.7 ± 13.0	16.2 ± 10.3
13	40-mile	29.5 ± 16.8	3.5 ± 2.8	53.7 ± 20.3	13.3 ± 6.9	14.2 ± 4.9
14	Eagle	42.6 ± 3.8	5.7 ± 2.6	26.0 ± 16.0	25.7 ± 20.9	2.8 ± 1.6
15	Yukon River-1	84.3 ± 15.5	3.0 ± 1.5	11.4 ± 15.4	1.3 ± 1.3	1.2 ± 1.0
16	Yukon River-2	68.0 ± 8.8	4.1 ± 2.7	19.5 ± 8.9	8.4 ± 8.3	6.0 ± 2.4
17	12-mile Summit	0	2.2 ± 4.6	62.4 ± 25.7	35.4 ± 21.7	15.0 ± 6.6
18	Fort Yukon	39.3 ± 6.8	5.8 ± 2.0	40.1 ± 7.7	14.8 ± 4.2	6.7 ± 1.3
19	Wiseman	30.6 ± 16.5	6.2 ± 4.2	52.9 ± 19.0	10.3 ± 5.2	26.8 ± 15.8
20	Kobuk	35.5 ± 21.0	7.3 ± 5.1	45.8 ± 11.3	11.4 ± 13.5	9.8 ± 3.2
21	Kiana	37.0 ± 16.0	5.2 ± 3.2	38.6 ± 20.8	19.2 ± 7.8	23.8 ± 6.0
22	Nulato	53.0 ± 22.0	3.3 ± 1.0	24.0 ± 19.9	19.7 ± 26.0	14.8 ± 6.0
23	Ruby	63.1 ± 17.6	6.4 ± 3.9	15.8 ± 9.6	14.7 ± 12.7	24.0 ± 16.8
24	Tanana	70.6 ± 17.2	2.2 ± 1.4	20.9 ± 11.4	6.3 ± 9.4	5.5 ± 1.2
25	Kantishna	4.5 ± 2.5	3.3 ± 3.3	72.2 ± 8.7	20.0 ± 9.1	23.8 ± 5.1
26	Deneki Lakes	0	2.9 ± 5.0	56.9 ± 35.9	40.2 ± 31.3	9.2 ± 4.8
27	Anchorage	54.3 ± 29.3	4.1 ± 1.4	25.4 ± 25.1	16.2 ± 26.8	25.0 ± 7.3
28	Kenai	14.9 ± 13.5	8.6 ± 1.6	42.0 ± 27.4	34.5 ± 36.2	40.2 ± 9.8
29	Fielding Lake[2]	--	--	--	--	--

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[1] First 4 data columns are based on filled seed fraction only. The empty seed column gives the average number of empty seeds per 100-seed replication.

[2] Fielding Lake seed not germinated. No observed seed contained embryos.

[3] Standard deviation.

[4] Includes empty seeds and those with poorly developed endosperm and embryo. The latter seeds often had a "mushy" consistency.

Table 5--*Embryo and endosperm condition as determined by dissection of seed*

(Percent of seeds)

Stand area	Embryo[1/]				Endosperm[2/]	
	I	II	III	IV	A	B
Bonanza Creek-1	0	0	0	100.0	100.0	0
Bonanza Creek-2	0	0	0	100.0	100.0	0
Bonanza Creek-3	0	0	0	100.0	100.0	0
Delta Junction	0	0	0	100.0	100.0	0
Gerstle River	0	0	0	100.0	100.0	0
Black Rapids	27.3	22.7	19.3	30.7	76.9	23.1
Tok	3.4	17.5	25.8	53.3	85.0	15.0
Eagle	3.1	0	0	96.9	95.9	4.1
Yukon River-1	0	0	0	100.0	100.0	0
Yukon River-2	0	0	0	100.0	100.0	0
12-mile Summit	75.0	25.0	0	0	0	100.0
Fort Yukon	0	0	0	100.0	100.0	0
Wiseman	12.5	5.7	20.4	61.4	90.9	0
Kobuk	0	0	0	100.0	100.0	0
Kiana	31.7	6.6	3.3	58.9	57.5	42.5
Deneki Lakes	64.2	35.8	0	0	29.3	70.7
Anchorage	2.5	0	5.0	92.5	98.8	1.2
Fielding Lake	100.0	0	0	0	0	100.0

[1/] Embryo class: I = Endosperm but no embryo; II = endosperm and one or several embryos, none of which is longer than half of the embryo cavity; III = endosperm and one or more embryos, the longest of which measures between half and three quarters of the embryo cavity; IV = endosperm with one fully developed embryo, completely or almost completely occupying the embryo cavity.

[2/] Endosperm class: A = The endosperm almost fills the seed coat to capacity. B = The endosperm does not fill the seed coat and is often shrunken or otherwise deformed.

Table 6--*Effect of stratification on real germination of Alaskan spruce seed*

Stand area	Stratified seed	Unstratified seed
	Percent real germination	
Chena River	97	93
Bonanza Creek-3	74	72
Delta Junction	95	31
Gerstle River	94	82
Black Rapids	68	22

Seed weight for the sources from which data were available ranged from 0.11 to 0.25 gram per 100 seeds (table 7). This range of seed weight falls within the ranges reported for white spruce by Hellum (1969) (0.13 to 0.32 gram per 100 seeds) and Safford (1974) (0.11 to 0.34 gram per 100 seeds). A comparison of average weights, however, indicates that average weight of Alaska seed (0.16 gram per 100 seeds) is less than that reported by Hellum (1969) (0.23 gram per 100 seeds) and Safford (1974) (0.20 gram per 100 seeds). It must be stressed that the seed lots in this study and those of Hellum (1969) and Safford (1974) may not be strictly comparable because of differences in such variables as percent filled seed and moisture content. Norin (1958) regarded low seed weights (0.12 to 0.26 gram per 100 seeds) for *Picea obovata* at similar latitudes in Russia as an indication of immaturity.

The correlation between seed quality as measured by real germination and seed weight for these data is poor. For example, stands Yukon River-1 (stand 15), Bonanza Creek-2 (stand 4), and T-field (stand 1), with the highest real germination, differed markedly in seed weight (0.1140, 0.1149, and 0.2302 gram per 100 seeds). Similarly, elevation and seed weight did not appear to be correlated.

These observations show that some stands in Alaska do not produce seed with mature embryos every year. Since these observations in 1970, we have observed seed immaturity in some of the same stands. On the other hand, seeds with immature embryos have not been observed in the Tanana Valley spruce stands during an 8-year period.

Table 7--*Seed weight*[1] *for Alaskan white spruce seed collected in 1970*

Stand area	Seed weight per 100 seeds and standard error	N[2]
	Grams	
T-field	0.1149 ± 0.0001	2
Bonanza Creek-1	.2174 ± .0221	2
Chena River	.1145 ± .0001	2
Bonanza Creek-2	.2302 ± .0343	4
Thinning area	.1860 ± .0240	1
Delta Junction	.2290 ± .0766	2
Gerstle River	.2052 ± .0116	4
Black Rapids	.1138 ± .0006	2
Klutina River-1	.1138 ± .0001	2
Tok	.1648 ± .0101	2
40-mile	.1141 ± .0002	1
Eagle	.1149 ± .0002	3
Yukon River-1	.1140 ± .0002	4
Yukon River-2	.1147 ± .0002	3
12-mile Summit	.1223 ± .0023	1
Fort Yukon	.2040 ± .0088	1
Wiseman	.1139 ± .0001	1
Kobuk	.1143 ± .0001	1
Nulato	.2489 ± .0477	2
Ruby	.2368 ± .0094	1
Tanana	.2411 ± .0414	2
Deneki Lakes	.1138 ± .0001	2

[1] Only seed lots with less than 5 percent empty seed were used.

[2] N indicates the number of trees from which seed could be used for weight determination.

CONE PRODUCTION AND SEED DISPERSAL

Cone Production

Counting of cones is easiest and counts are most accurate in July after cones have attained maximum size and well before squirrels begin to harvest them. Because environmental conditions (for example, frost) can reduce cone numbers, the cones observed in July may not be an adequate estimate of the number of cones at bud break. For insight into the problem of cone mortality, the following observations were made:

For an estimate of cone losses, 100 cones were tagged about June 1 on each of six trees. These cones were examined periodically and recounted in August. The death of a single cone on each of two of these trees before June 1 was the only reduction in cone number that occurred. Although Zasada (1971) observed significant cone losses caused by subfreezing temperatures in 1970, a frost which occurred in stands 1 (T-field) and 3 (Chena River) did not result in observable damage. Temperatures at this time (June 9) dropped to -2°C for 4 to 6 hours. These subfreezing temperatures occurred at a time when the cones were relatively resistant to mild freezing (Zasada 1971).

A further test was conducted to determine if absence of pollination resulted in cone mortality, as Sarvas (1957) reported for Scotch pine (*Pinus sylvestris* L.). Two branches from three of the trees observed for cone survival were enclosed in a pollination bag before pollen dispersal began. Fifty cones on each tree were treated in this manner. After these cones were no longer receptive, the bags were removed; in August the cones were collected and counted and seeds examined. None of the cones had died. X-ray analysis revealed no filled seeds in unpollinated cones (fig. 10). The cones from the unpollinated branches were much smaller than those exposed to open pollination, but no other morphological differences were observed.

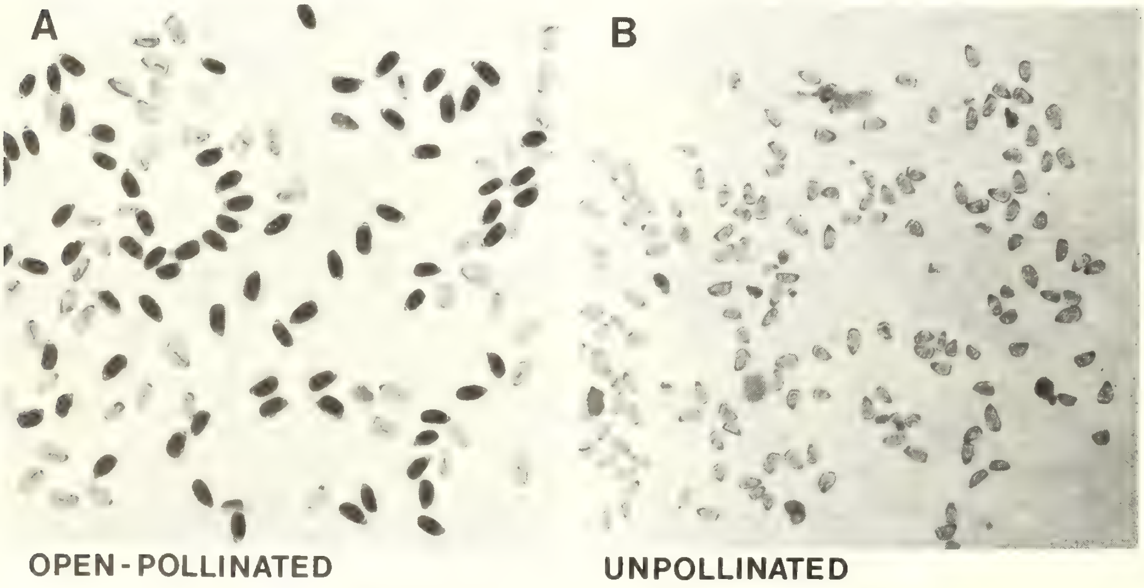

Figure 10.--Seed produced by (A) open-pollinated and (B) unpollinated white spruce cones.

In summary, although a mild frost occurred in some stands about 2 weeks after pollination, there was no evidence of frost damage to the cone crops in any stand in which cones were counted. No cone mortality was observed on six sample trees, and nonpollination did not result in cone mortality. Thus, at least for 1970, the number of cones on the trees at the time of the cone counts was a good estimate of the number of cones at the time of bud break.

In each stand where seed traps were located (table 1), 15 or 16 trees were selected and partial cone counts were made. The counts were made from one point with a variable power (15X to 60X) spotting telescope. Thus, the total cone crop is not represented, only the number of cones visible from one side of the tree. The number of cones counted can be considered only an approximation of the actual number because of the difficulty of seeing all cones. The accuracy of the approximation decreases as the number of cones produced increases. Problems associated with accuracy of cone counts are discussed by Machaniček (1973).

These counts indicated that no tree in any stand (except stand 16) had fewer than 100 cones and that most trees had 300-500 or more cones. In stands 2, 3, 4, 6, and 15 (Bonanza Creek-1, Chena River, Bonanza Creek-2, Bonanza Creek-3, and Yukon River-1), some trees had a minimum of 800-1,500 cones per tree (table 8).

Table 8--*Number of cones produced*[1/] *in mature white spruce stands in Alaska in 1970*

Tree number	Stand area							
	Bonanza Creek-1	Bonanza Creek-2	Bonanza Creek-3	Chena River	Klutina River-1	Klutina River-2	Yukon River-1	Yukon River-2
1	350	800	420	1,280	500	500	434	29
2	800	1,100	406	1,560	124	321	133	390
3	327	1,300	338	610	240	260	619	40
4	350	700	230	848	250	377	361	433
5	756	550	121	905	350	469	600	228
6	652	585	177	856	322	207	374	514
7	602	415	416	808	173	209	405	152
8	600	775	309	932	460	986	329	176
9	500	419	530	1,000	270	445	475	440
10	100	360	806	730	200	415	410	467
11	482	217	950	705	371	282	900	258
12	434	400	930	560	288	503	585	271
13	300	850	310	448	500	170	800	500
14	436	900	418	800	400	258	390	350
15	421	470	522	219	272	643	500	132
16	400	--	--	--	216	--	--	--

[1/] Number of cones visible on one side of the tree.

All stands had some cones harvested by squirrels. In all but stand 3 (Chena River), however, the squirrels appeared to reduce the number of cones only slightly. In stand 3, cone counts made in early September showed that the crops of all but one-third of the trees had been reduced by 80 percent or more. Based on cone count data, this stand had at least as many cones originally as other stands. Stand 3, however, ranked last among undisturbed stands in the total amount of seed dispersed (table 9).

Table 9--*1970 seed fall in Alaskan white spruce stands*

Stand area	Number of seeds per square meter	Number of filled seeds per square meter	Filled seeds
			- - Percent - -
Bonanza Creek-1	1,003	609	60.7
Bonanza Creek-2	2,068	1,595	77.1
Bonanza Creek-3	1,038	615	59.2
Chena River	252	128	50.8
T-field	1,121	635	56.6
Thinning Area	950	431	45.4
Klutina River-1	2,076	1,100	53.0
Klutina River-2	415	157	37.8
Chena (cutover)	31	16	51.6
Clayton (cutover)	435	294	67.6

Seed Production and Dispersal

METHODS

For observation of seed fall, ten 0.5-square-meter, funnel-shaped seed traps were placed in each of 12 stands. Ten of these stands were undisturbed (table 1) and two were cutovers. Stands 15 and 16 (Yukon River 1 and 2) were flooded during spring breakup in 1971 and yielded no seed fall data. The sampling surface was located about 1.4 meters above the ground. In all stands the traps were serviced in July or August 1970. In stands 2 and 3 (Bonanza Creek-1 and Chena River), collections were made from the traps at 7- to 10-day intervals from August until January and at about monthly intervals thereafter. The last collection was in early August 1972. In the other stands, collections were made in early November 1970 and late July 1971. After collection, the seeds were separated from the litter and counted. Filled seed percentage was determined by a cutting test. Only seeds containing an embryo and more than three-fourths filled by the endosperm were classed as filled.

RESULTS AND DISCUSSION

Seed dispersal in the study trees in stand 1, T-field, had started by September 2, about 99 days after pollen dispersal (this assumes that pollination occurred on May 26). Cram and Worden (1957) reported 97-99 days and Crossley (1953) 108 days. Tree 6 was most advanced in this respect; all but a few cones were open and dispersing seed on September 2. Trees 2, 4, and 5 had not dispersed seed on September 2; by September 10, however, 50 percent or more of the cones on these trees were open and dispersing seed. Tree 1 was intermediate with a few cones open on September 2 and all cones dispersing seed by September 10.

The start of seed dispersal as measured by weekly collections from seed traps in stands 2 and 3 (Bonanza Creek-1 and Chena River) agreed with observations in stand 1 (T-field). The first significant quantity of seed was dispersed in stand 2 between September 3 and 10; in stand 3, between September 1 and 8.

The seasonal pattern of dispersal observed is similar to that reported for these same stands in 1968 (Zasada and Viereck 1970) (fig. 11, table 10). Although the majority of the seed was dispersed prior to January, there were still significant amounts of filled seed (7 and 15 percent) remaining in the cones. During a good seed year such as 1970, this quantity of seed could be adequate for seeding winter scarified seed beds. The seed dispersed from September 1971 through August 1972 is attributed to the 1970 crop because no cone production was observed in 1971.

Table 10--*Cumulative dispersal of the 1970 seed crop*

(In percent)

Stand, seed fall, and filled seed	1970					1971							From Sept. 1971 to Aug. 1972
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July-Aug.	
Stand 2:													
Total seed fall	0.5	51.5	68.1	86.8	87.2	88.4	89.5	91.7	94.5	97.3	97.9	98.0	100.0
Filled seed	0	57.8	73.3	91.2	92.6	93.3	94.1	95.4	96.7	98.4	98.6	98.7	100.0
Stand 3:													
Total seed fall	4.3	46.0	60.9	75.5	80.0	83.4	85.1	92.8	95.1	95.7	96.8	97.4	100.0
Filled seed	3.6	56.2	68.4	75.2	83.1	85.5	86.7	95.2	98.2	98.8	99.4	99.4	100.0

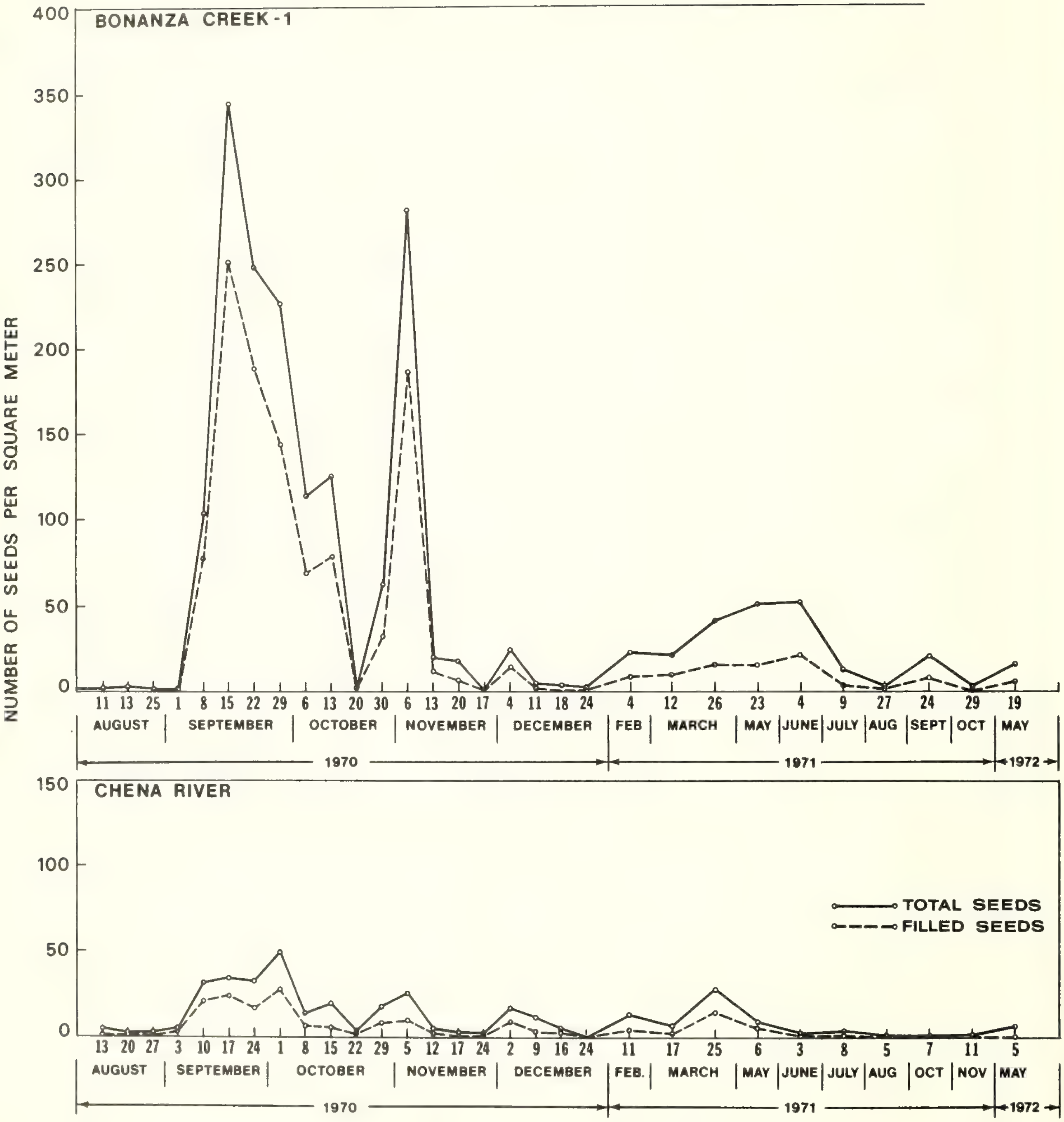

Figure 11.--Annual seed dispersal in two mature white spruce stands (stand 2, Bonanza Creek-1, and stand 3, Chena River).

Total seed fall in all undisturbed stands was greater than 250 seeds per square meter (1 million per acre). Greatest production was about 2,000 seeds per square meter (8 million per acre) in stands 4 (Bonanza Creek-2) and 10 (Klutina River-1). Stands 4 and 10 produced the greatest quantity of filled seed (table 9). In 1958, the last excellent seed year, the estimated production in stand 4 was approximately twice that in 1970 (Zasada and Viereck 1970). In two partially cut white spruce stands, seed fall estimates were 31 (total) and 16 filled seeds per square meter (128,000 and 66,000 per acre) and 435 and 294 seeds per square meter (1.8 million and 1.2 million per acre). The largest spruce seed crop reported in North America of 5,450 (total) and 3,030 filled seeds per square meter was for red spruce (*Picea rubens* Sarg.) in New Brunswick (Powell 1975).

Germination and Seedling Establishment

The final phase of the natural regeneration portion of forest management begins as soon as the seed lands on the seed bed. From this time until the seedling becomes established, a complex set of biological, physical, and chemical variables interact with the seed and the various stages of seedling development to determine the success or failure of regeneration. The observations made in this study were primarily concerned with the dynamics of the white spruce seedling population on a mineral soil seed bed over a 5-year period. The most detailed observations were made of germination and 1st-year survival and selected physical environmental variables. Similar observations were made for paper birch because this species is one of the major trees associated with white spruce in interior Alaska. A knowledge of the regeneration potential of birch is critical to a thorough understanding of white spruce management. The changes in other plant species associated with changes in the white spruce seedling population were also recorded.

Although white spruce has been used for firewood, house logs, mine timbers, and lumber in interior Alaska since the early 1900's, little thought was given to securing natural regeneration. To our knowledge our study was the first formal attempt to obtain natural regeneration of white spruce in Alaska; thus, one of the main objectives of this study was to provide a small-scale demonstration of the regeneration potential during an excellent seed year. A secondary objective was to test methods for assessing natural regeneration in a larger study which began in 1972.

METHODS

The area for the natural regeneration part of our study is an upland site in the Bonanza Creek Experimental Forest located 15 km southwest of Fairbanks, Alaska, and 0.5 km from stand 4, Bonanza Creek-2. This area is a gently sloping (approximately 10-percent slope) south-southwest-facing site, typical of upland white spruce sites in this area. The original stand contained 75-percent white spruce and 25-percent paper birch. The soil is a deep phase of the Fairbanks silt loam series and has developed in loess parent material.

In July 1970 a 0.59-hectare (77- by 77-m) area was cleared of all vegetation except for several dominant white spruce which were left as a seed source. Within this larger clearing, a 0.1-hectare (31- by 31-m) area was cleared of all organic matter. Five 0.5-square meter seed traps were used to estimate seed fall. These traps were emptied annually after snowmelt in late April or May and in August. Percent filled seed was estimated from cutting tests. Viability of filled seed in stand 4 (Bonanza Creek-2) was 85 percent (table 4). Figure 12 shows the general nature of the study area and the vegetation recovery at the end of the third growing season.

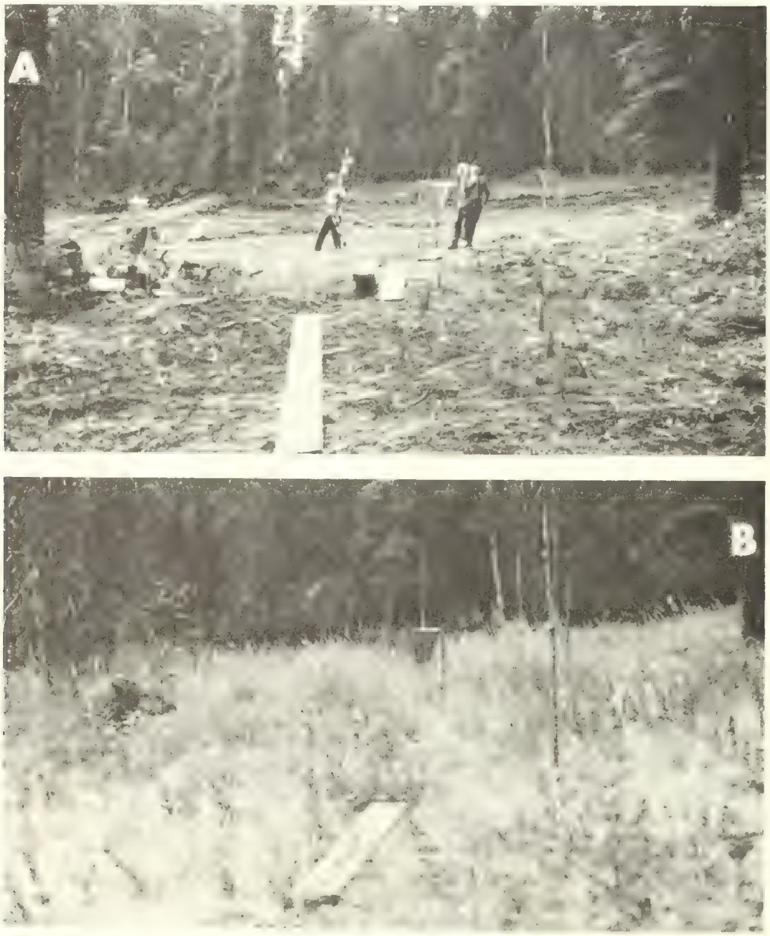

Figure 12.--General view of a portion of the forest opening in which seedling establishment was observed (A). Note vegetative recovery after 3 years (B). The funnel-shaped seed trap is an example of traps used in the seed fall observations in this area and in the 12 stands mentioned earlier.

Plots for observation of seed germination and seedling survival and general vegetative development were established on mineral soil shortly after site preparation. Spruce seedling plots were 60 cm in diameter (0.283 square meter) and birch plots were 20 cm (0.031 square meter); 20 plots were used for each species. The total number of seedlings on which the observations are based is shown in table 11.

Table 11--*Number of first growing season germinants and surviving seedlings produced during the 1st, 2d, 3d, and 5th growing seasons*

Germinants	1971				1972	1973	1974 and 1975
	May-June	July	August	Total			
White spruce:							
Total germinants	605	549	265	1,419	0	--	--
Survivors after 1 growing season	325	458	189	972	0	194	0
Paper birch:							
Total germinants	331	302	197	830	--	--	--
Survivors after 1 growing season	163	221	128	512	72	86	0

During the first growing season (1971), weekly observations were made from mid-May through September. New seedlings were marked with toothpicks. During 1972, observations were made in the early summer and fall; in 1973 and 1975 in the fall only. Changes in cover and frequency of vascular and nonvascular plants were observed in twelve 1 m^2 plots in August of 1971, 1972, 1973, and 1975. Seedling growth observations consisted of weekly excavations of seedlings during 1971. The seedlings which were excavated represented the most well-developed seedlings within the study area. Development was assessed on the basis of aboveground growth.

Soil temperatures were monitored in the area during the first growing season using Tempils[1/] and thermistors. Rainfall data were obtained from a weather station located in a similar opening about 1 km from the study area (Barney and

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[1/] The use of trade, firm, or corporation names is for the convenience of the reader and does not constitute an official endorsement by the U.S. Department of Agriculture.

Berglund 1973). Weekly soil moisture determinations were made gravimetrically at 0- to 2-, 3- to 5-, and 6- to 8-cm depths; moisture measurements were replicated four times. The soil sampler used was 4 cm in diameter. Soil moisture content was converted from a weight basis to a volume basis.

RESULTS AND DISCUSSION

Germination

Germination of white spruce and paper birch seed began between May 21 and May 28, 1971; the last new germinants were observed in early September. The average germination pattern for these species was characterized by peaks in late May to early June and late July to early August (fig. 13). This generalized pattern is misleading, however. In reality, the two-peaked character is due to the occurrence of germination on about 50 percent of the plots during the first peak; the second peak resulted from germination which occurred on the latter plots plus those plots which had essentially no germination in May and June.

The germination pattern observed in this study was also reported for white spruce seed (natural seed fall) in Manitoba (Waldron 1966). This was not the most common pattern observed in Manitoba; Waldron reported that over a 4-year period, 67 and 27 percent of white spruce germination occurred in June and July, respectively. Waldron also noted that little germination was observed in May; in our study, the highest average number of white spruce germinants per plot was observed in late May. Horsley and Abbott (1970) observed that germination of spring-seeded birch was 70 to 80 percent complete within 4 weeks of artificial seeding.

In other field germination studies in Alaska, 85 percent of white spruce seedlings produced by naturally dispersed seeds and present at the end of the 1969 growing season had germinated prior to June 24 (Zasada and Gregory 1969), a result similar to the dominant pattern observed by Waldron (1966). Clautice2/ reported that peak germination of spring-seeded spruce and birch occurred before the 1st week in July on north aspects. On south aspects, peak birch germination occurred earlier and spruce germination later relative to that on north aspects.

Germination patterns reflect temperature and moisture conditions. Although the water availability observations made in this study do not indicate the moisture stress conditions to which the seeds were exposed, they do provide the rainfall input and an approximation of seed bed dryness

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2/ Clautice, Stephen F. 1974. Spruce and birch germination on different seed beds and aspects in interior Alaska. 68 p. Master's Thesis, Univ. Alaska, Fairbanks.

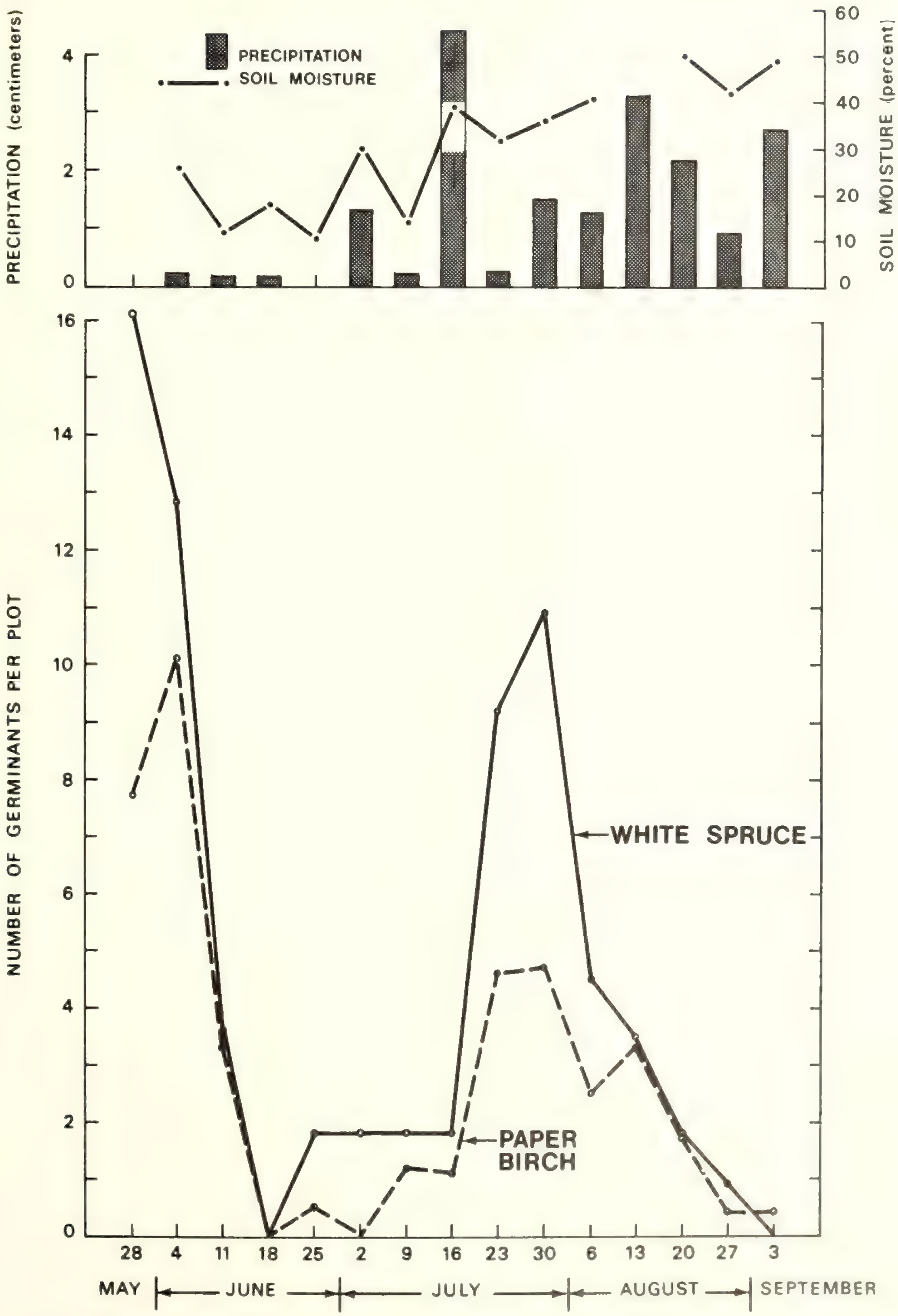

Figure 13.--Seasonal germination patterns of the 1970 white spruce and paper birch seed crops, precipitation, and soil moisture (volume basis, at 0-2 cm).

(fig. 13, table 12). The early germination was associated with high surface-soil moisture after snowmelt. The lull in activity was associated with a period of little rainfall when surface soil moisture was less than 20 percent. The July 2 moisture content was 30 percent, but this level was not maintained. In addition to lower average surface soil moisture, the water content in these layers was highly variable. Minimum moisture contents were from 3 to 4.5 percent. The second peak in germination occurred after relatively heavy rains preceding July 16. This and subsequent rain maintained average surface-soil moisture at 30 percent or greater. In addition, relative humidity was generally higher in July and August than in June (Barney and Berglund 1973).

Table 12--*Soil water content during the 1970 growing season*

Date	Depth (centimeters)						Precipitation
	0-2		3-5		6-8		
	$\bar{X}$	Range	$\bar{X}$	Range	$\bar{X}$	Range	
	Percent						Centimeters
June 4	26.1	4.4-37.9	24.5	13.8-36.0	31.1	19.4-38.9	0.02
June 11	12.3	3.0-18.8	25.0	14.1-34.3	24.1	17.0-30.2	.18
June 18	18.1	3.2-30.6	22.8	11.3-36.3	24.2	16.6-32.2	.18
June 25	10.5	3.3-23.8	20.3	10.6-31.2	22.6	18.7-24.8	0
July 2	29.7	27.2-33.9	30.4	29.2-31.5	30.4	23.8-36.1	1.27
July 9	14.2	10.1-20.6	23.9	16.4-30.9	26.5	17.8-23.4	.10
July 16	39.0	24.9-50.8	45.4	40.8-52.1	41.0	38.1-48.3	4.41
July 23	31.6	16.6-43.0	35.2	31.9-43.4	33.2	27.5-42.4	.22
July 30	36.3	29.5-44.1	39.0	35.0-44.9	38.0	28.0-50.8	1.49
Aug. 6	40.8	32.9-51.2	36.4	32.0-39.7	38.6	36.6-41.0	1.24
Aug. 13	--	--	--	--	--	--	3.30
Aug. 20	50.3	47.3-56.2	47.8	38.4-53.8	44.0	38.2-48.7	2.10
Aug. 27	41.8	35.3-45.3	40.2	34.7-47.2	38.8	35.4-42.4	.96
Sept. 3	48.9	39.0-56.3	37.8	40.0-51.1	38.9	35.2-44.6	2.77

Soil temperatures at the time germination began were 19° to 23°C (maximum) and 3° to 10°C (minimum). During the period when little or no rain fell and germination rate was low, surface temperatures as high as 40° to 50°C were observed. After early July when precipitation was occurring regularly, maximum surface temperature did not exceed 35°C and minimum surface temperatures were from 4° to 16°C.

The germination patterns for white spruce and birch were similar. Seeds germinating during the second peak are assumed to have been on the site during the first germination period. Their germination was prevented by adverse moisture or temperature conditions. The above assumption is based on the pattern of annual seed dispersal (fig. 11). That is, insignificant quantities of spruce and, it is assumed, birch seeds were dispersed in late June or July to account for the number of germinants which appeared during the second peak.

Survival and Population Dynamics

Survival during the first three growing seasons was assessed by subdividing the 1971 cohort (seedlings grown in the same year) into three subpopulations: those germinated prior to July 2 (May through June), July 3 to July 30 (July), and after July 30 (August). In both spruce and birch, summer survival was lowest for the May through June germinants. These seedlings were subjected to the most severe moisture and temperature conditions. Heaviest mortality for July and August spruce germinants and the June birch germinants occurred during the dormant season (table 13). At the end of the third growing season, the 1971 spruce cohort consisted of 60 percent May through June germinants, 32 percent July, and 8 percent August; the birch cohort consisted of 25, 47, and 28 percent June, July, and August germinants (table 14).

Table 13--*Percentage of white spruce and paper birch seedlings which survived the first summer and winter, by month of germination*

Seedlings	May-June		July		August	
	Summer survival[1]	Winter survival[2]	Summer survival	Winter survival	Summer survival	Winter survival
White spruce	53.8	48.0	83.2	20.1	71.2	15.9
Paper birch	49.2	41.7	73.2	58.8	65.0	57.0

[1] Percentage of all germinants for specified period.

[2] Percentage of seedlings surviving the first growing season.

Table 14--*Percentage of surviving 1971 white spruce and paper birch seedlings at the end of the first 3 growing seasons by month of germination*[1]

Species	1971			1972			1973		
	May-June	July	August	May-June	July	August	May-June	July	August
White spruce	33.4	47.2	19.4	56.1	33.1	10.8	59.8	32.2	8.0
Paper birch	31.8	43.2	25.0	25.1	48.0	26.9	25.3	46.5	28.2

[1] Percentage of seedlings alive at the end of each growing season.

White spruce and birch survival patterns differed during the 5-year period even though the percent survival was almost identical at the end of 5 years. This contrasts with the germination patterns mentioned earlier, which were similar. White spruce exhibited relatively little decline in density after the massive mortality of the first summer and winter. Birch survival, on the other hand, decreased relatively uniformly over the period (fig. 14, table 15).

Growth of the 1971 seedlings during their first growing season is shown in figure 15. Seedlings selected for each date represented the most vigorous individuals, and the sequence for both species best represents the shoot and root development of the earliest germinants. At any one time, seedlings representing all stages of development could be found. The July and August germinants are probably best represented by the germinants prior to those of July 2. Of particular interest is the relatively large size attained by dominant birch seedlings.

Place (1957), Waldron (1966), and Ronco (1967) reported, as observed in this study, differential winter mortality of conifer seedlings related to the time during which germination occurred (table 13); that is, spruce seedlings which germinated in July and August suffered more overwinter mortality than those germinating earlier. Birch exhibited a different pattern in that July and August germinants survived the winter better than those from June. In a study conducted in the subalpine forests of Alberta, Ackerman (1957) reported that survival in two artificial seeding experiments (fall seeded) was 76 and 35 percent at the end of the second growing season. Horsley and Abbott (1970) reported that 1st-year summer survival for paper birch ranged from 54 to 86 percent, winter survival from 31 to 56 percent, and survival at the end of the second growing season was from 24 to 47 percent.

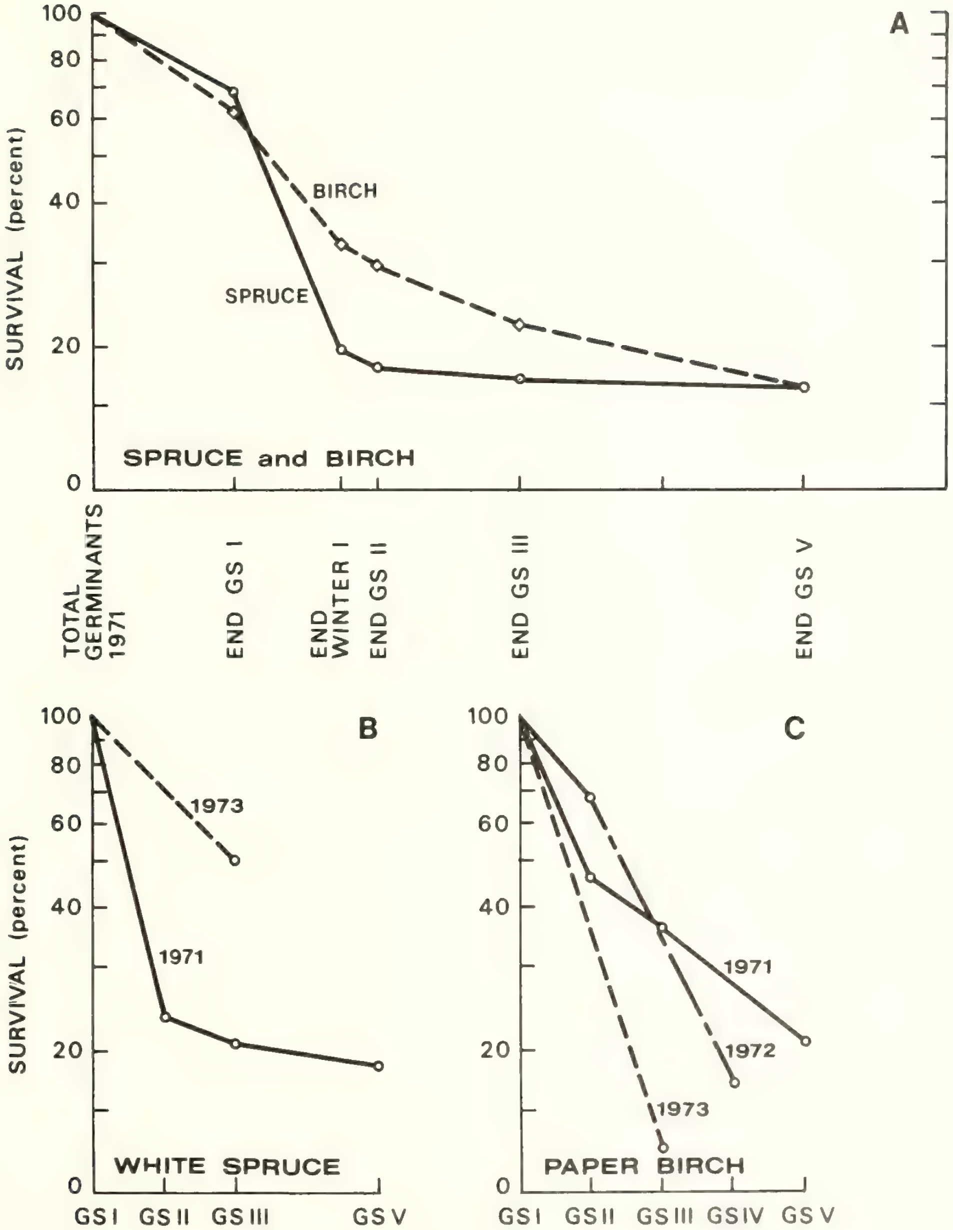

Figure 14.--Survival of white spruce and paper birch seedlings over five growing seasons (1971-75): A, 1971 spruce and birch germinants; B, 1971 and 1973 spruce germinants; C, 1971, 1972, and 1973 birch germinants. GS = growing season.

Table 15--*White spruce and paper birch seedling population composition by year of germination*

Item	1971	1972			1973				1975				
	Year of germination	Year of germination			Year of germination				Year of germination				
	1971	1971	1972	Total	1971	1972	1973	Total	1971	1972	1973	1974 and 1975	Total
						Number of seedlings per plot[1]							
White spruce	48.6	11.4	--	11.4	10.0	--	9.7	19.7	9.0	--	4.9	0	13.9
Standard error	20.7	8.8	--	8.8	7.8	--	8.3	9.6	6.8	--	4.9	--	7.5
Frequency[2]	100	95	--	95	95	--	90	100	95	--	80	--	100
Paper birch	25.6	11.8	3.6	15.4	9.2	2.4	4.3	15.9	5.3	.5	.2	0	6.0
Standard error	16.8	12.2	2.8	12.9	9.2	2.1	3.9	10.3	6.6	.9	.4	--	6.3
Frequency	95	85	75	90	85	75	80	95	80	30	20	--	90

[1] For conversion to density per square meter, multiply spruce by 3.5 and birch by 31.8.

[2] Frequency on germination plots. Frequency on square-meter vegetation plots, 100 percent for both species.

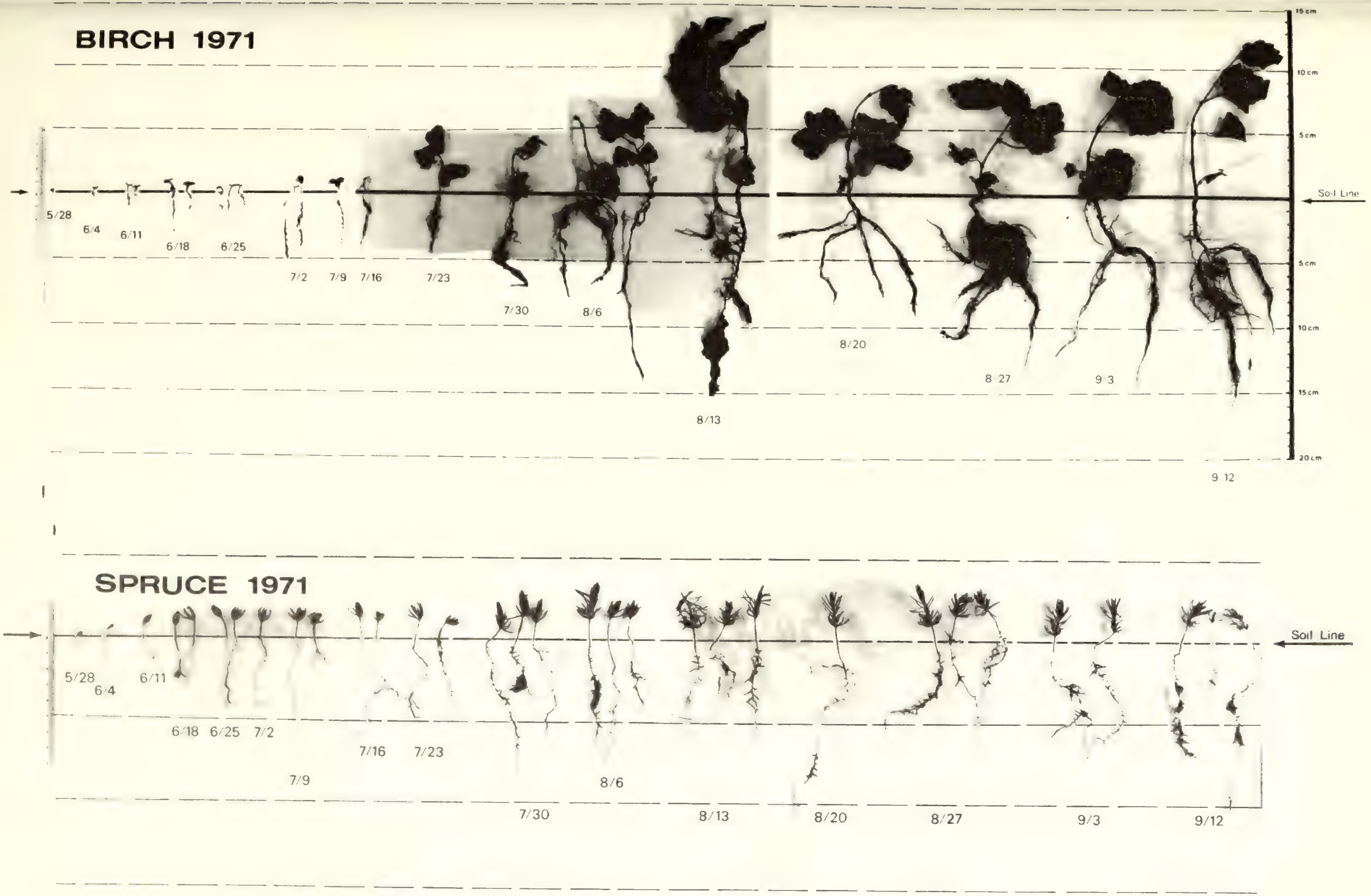

Figure 15.--Development of white spruce and paper birch seedlings as indicated by weekly excavation of vigorous seedlings.

Germinants were added to the spruce population in 1973 and to the birch population in 1972 and 1973 (table 15). The 1973 germinants were the result of heavy seed fall by both species in 1972 (spruce, 531 filled seeds per square meter (table 16); birch, 1,800 per square meter). By the end of the 1975 growing season, these seedlings contributed 35 percent to the spruce population and 12 percent to the birch population (a comparably poor contribution).

Table 16--*White spruce seed fall in a forest opening in interior Alaska for seed years 1970-74*

Year	Total seed per square meter	Filled seed per square meter
1970	960 ± 26[1]	666 ± 20
1971	44 ± 5	18 ± 5
1972	996 ± 76	531 ± 38
1973	68.0 ± 11	20 ± 8
1974	0	0

[1] Standard deviation.

The dominant seedlings in the study area, however, were those produced by the 1970 seed crop. Dominant spruce seedlings of 1971 origin averaged 18.5 cm tall while those produced in 1973 were 5 cm; the birch produced in 1971 were 29.4 cm tall at the end of 1975. Barring natural disaster, it appears that the seedlings from the 1970 seed crop will continue to dominate the area.

Seed crop efficiency can be measured by seedling:seed ratios. The following tabulation compares the estimates for white spruce from this study with those reported by Ackerman (1957).

	Growing season		
Year of germination	First	Third	Fifth
	(Number of seedlings:number of seeds)		
1971 (present study)	1:4	1:18	1:21
1973 (present study)	1:16	1:31	--
Experiment 1 (Ackerman 1957)	1:7	1:11	1:13
Experiment 2 (Ackerman 1957)	1:13	1:42	1:67

The 1971 values and Ackerman's values are for mineral soil seed beds where all vegetation was removed, conditions reported to be the most desirable for germination and initial establishment (Dobbs 1972). The other extreme is represented by seed beds consisting of organic matter of varying depths. Under these conditions Ackerman (1957) reported ratios of one seedling per 228 seeds and Eis (1967b) 1:200 seeds. In interior Alaska where organic and moss layers tend to be thicker, these ratios are probably higher. Comparative values for the 1972 birch seed crop were 1:450 and 1:9,000 after one and three growing seasons.

Seedling production by two essentially identical seed crops (table 16), relative seedling size, poorer performance by birch seedlings produced by the 1971 and 1972 seed crops, and the associated changes in soil surface conditions and plant cover provide insight into the question of the deterioration of seed bed conditions and an environment suitable to seedling survival. Site preparation created large areas of mineral soil for the 1970 seed crop. By 1972, however, the area covered by mineral soil had decreased to 19 percent even though frequency of occurrence was 100 percent; in 1975, exposed mineral soil was 3 percent and frequency 67 percent (table 17).

The primary reasons for the decline in the area of exposed mineral soil were increased plant litter and moss cover (table 17). The effect of moss cover on seedling establishment goes beyond the influence its growth has on the area of exposed mineral soil. By 1975, the height of the moss was equal to that of the 1973 seedlings and was in a position to compete with seedlings for moisture, light, and nutrients. These data suggest that seed beds remain receptive for 3 to 5 years for spruce and for a shorter time for birch under the study conditions. These results for spruce agree in general with those from central British Columbia (Arlidge 1967).

Woody and herbaceous plant cover changed significantly between 1971 and 1973 (table 17). These changes were the reason for the annual increases in area covered by plant litter; they created a different light, chemical, and moisture environment within the soil and air layers most important to germination and seedling survival. By the end of the 1973 growing season, plant cover on the meter-square plots averaged 90 percent. Birch and horsetail (*Equisetum arvense* L.) were the dominant species in terms of cover. In addition to the potential competitive and inhibitive (allelopathic) effects of this vegetation, there is also the possibility of physical damage to seedlings resulting from litter fall. Gregory (1966)

Table 17--Changes in seed bed conditions and frequency and percent cover of vascular and nonvascular plants, litter, and exposed mineral soil in a forest opening in interior Alaska

(In percent)

Seed bed conditions and plants	1971 (May)	1971 (Sept.)	1972	1973	1975
SEED BED CONDITIONS					
Mineral soil:					
Frequency	100	100	100	83	67
Cover	85	72	19	14	3
Leaf litter:					
Frequency	100	100	100	100	100
Cover	7	8	10	24	89
Other litter:					
Frequency	--	42	92	100	17
Cover	--	2	2	2	1
NONVASCULAR PLANTS					
Liverworts:					
Marchantia polymorpha--					
Frequency	--	25	8	33	8
Cover	--	1	1	1	3
Mosses:					
Ceratodon purpurea--					
Frequency	--	--	--	100	75
Cover	--	--	--	65	6
Polytrichum spp.--					
Frequency	--	--	--	92	100
Cover	--	--	--	18	25
Other mosses--					
Frequency	8	83	50	90	50
Cover	1	28	21	1	1
VASCULAR PLANTS					
Herbs:					
Epilobium angustifolium--					
Frequency	25	75	75	100	100
Cover	1	8	11	9	6
Calamagrostis canadensis--					
Frequency	8	50	58	67	75
Cover	1	3	10	13	22
Equisetum arvense--					
Frequency	--	100	100	100	100
Cover	--	6	25	24	22
Geranium Bicknellii--					
Frequency	--	92	92	92	75
Cover	--	8	14	2	1
Corydalis aurea--					
Frequency	--	75	42	8	--
Cover	--	5	1	1	--
Moehringia lateriflora--					
Frequency	--	8	17	8	33
Cover	--	1	1	1	1
Mertensia paniculata--					
Frequency	--	8	17	8	8
Cover	--	1	1	1	1
Agrostis scabra--					
Frequency	--	8	8	50	42
Cover	--	1	1	1	2
Galium boreale--					
Frequency	--	8	8	8	8
Cover	--	1	1	1	1
Solidago or *Erigeron*--					
Frequency	--	8	--	8	17
Cover	--	1	--	1	1
Taraxacum spp.--					
Frequency	--	--	8	8	8
Cover	--	--	1	1	1
Low shrubs:					
Vaccinium vitis-ideae--					
Frequency	--	--	--	--	8
Cover	--	--	--	--	1
Tall shrubs:					
Viburnum edule--					
Frequency	--	17	8	8	8
Cover	--	1	1	1	1
Ribes triste--					
Frequency	--	50	67	92	83
Cover	--	3	3	1	2
Rosa acicularis--					
Frequency	--	17	33	33	33
Cover	--	1	1	1	1
Salix spp.--					
Frequency	--	--	50	75	42
Cover	--	--	1	1	1
Salix arbusculoides--					
Frequency	--	--	--	50	33
Cover	--	--	--	1	2
Salix alaxensis--					
Frequency	--	--	--	42	42
Cover	--	--	--	1	1
Alnus crispa--					
Frequency	--	--	--	8	17
Cover	--	--	--	1	1
Betula papyrifera--					
Frequency	--	100	100	100	100
Cover	--	9	23	32	37
Picea glauca--					
Frequency	--	100	100	100	100
Cover	--	1	2	2	11
Populus tremuloides--					
Frequency	--	--	25	50	42
Cover	--	--	1	1	1
Populus balsamifera--					
Frequency	--	--	17	25	25
Cover	--	--	1	1	1

reported that white spruce seedlings less than 4 years old could be damaged or smothered by leaf fall in an 80-year-old birch stand. The nature of the litter produced by the herbaceous and woody vegetation on this site is significantly different from that in an 80-year-old birch stand, but the litter could have damaged spruce and birch seedlings which germinated in 1973.

The dominant vascular plants which regenerated in abundance, in addition to spruce and birch, were fireweed (*Epilobium angustifolium* L.), horsetail, and bluejoint (*Calamagrostis canadensis* (Michx.) Beauv.). These species are all common in undisturbed white spruce stands. Two species, *Geranium Bicknellii* Britt. and *Corydalis aurea* Willd., which were not found in the undisturbed white spruce stands, were important during the first two growing seasons after clearing. By the end of the fifth growing season, *Corydalis* was no longer present on the plots. *Geranium* was still present; however, its frequency of occurrence had declined from 92 to 75 percent and its percent cover had decreased from 14 percent (second growing season) to less than 1 percent. Tall shrubs had low percent cover; but the willows (*Salix* spp.), as a group, and American red currant (*Ribes triste* Pall.) had relatively high frequencies of occurrence (table 17).

Management Implications

We feel that the observations reported here have demonstrated several potentially important things to land managers interested in obtaining natural regeneration of white spruce. These are:

1. White spruce stands in three areas of Alaska produced large cone and seed crops. This indicates that the basic seed input is periodically available over much of this species' range in the State.
2. Weather conditions can prevent the maturity of seed crops. In 1970, immaturity occurred in stands above 600 m and north of the Arctic Circle. These observations indicate that if seed collection from a given area is necessary, seed development should be monitored closely to determine the right time to collect cones. The best method of handling cones should be used to insure that seed of the highest possible quality is secured.
3. Seed disperal began in early September. Thus, site preparation should be accomplished earlier to get maximum benefit from a particular seed crop.
4. Abundant white spruce (and paper birch) natural regeneration can be obtained on upland sites in the Tanana Valley during an excellent seed year. The receptivity of the seed bed is significantly decreased by the third growing season, making adequate germination and seedling survival increasingly difficult to obtain. When possible, site preparation should coincide with an adequate seed year.

It must be stressed that the general applicability of the results of this study must be tested over a period of years and different soil and site conditions. The main importance of the observations is that they indicate, in general, white spruce natural regeneration follows similar patterns to those observed elsewhere. An important departure from the generalized North American regeneration considerations, but not from those of northern Finland, Sweden, and Norway, is the limitation on natural regeneration which may occur in some years as a result of immature seed crops.

Summary

The 1970 cone and seed crop for white spruce was the best crop recorded since 1958. Climatic conditions considered favorable for formation of reproductive buds occurred in 1969, resulting in a large number of male and female flowers in the spring of 1970. This paper reports on male strobili development and pollen dispersal, cone development, seed maturation and dispersal, and the germination of seed and survival of the seedlings produced by this seed crop.

1. In 1970, flowering in white spruce was found to be strongly influenced by elevation. Flowering at low elevation (135 m) occurred from May 25 to 27; at higher elevations (600 m or higher), flowering was 3 to 5 weeks later.
2. Cone size was significantly influenced by seed source. In the Fairbanks area cone expansion was completed by July 1. Dry weight continued to increase until mid-July. Percent moisture content decreased sharply from early July to mid-July, decreased gradually from mid-July to mid-August, and decreased more rapidly from mid-August until seed dispersal began.
3. At lower elevations, seed maturity increased steadily from early July to early August. Poor seed development (immature embryos) was observed in stands above 600 m and north of the Arctic Circle.
4. Seed dispersal in the Fairbanks area began 99 days after pollination. Total seed fall in undisturbed white spruce stands varied from 250 to 2,000 seeds per square meter (1 to 8 million per acre). Percent filled seed was 38 to 77 percent.
5. Seed germination began in late May and was characterized by peaks in late May and early June and late July and early August. This seasonal pattern was associated with summer moisture availability.
6. White spruce seedlings which germinated in May and June 1971 had the highest survival over a 3-year period. The greatest mortality occurred in the summer and winter after germination.

7. At the end of 5 years, the white spruce seedlings produced by the 1970 seed crop comprised 65 percent of the spruce seedlings in the study area and the dominants produced by this seed crop were at least two to three times larger than those produced by the 1973 seed crop.

8. Seed bed and seedling survival conditions had deteriorated significantly by the end of the third growing season.

9. Observations made of paper birch germination and survival indicated that the germination pattern for birch was similar to that of spruce. Survival differed in that birch seedling density decreased more gradually over the 5-year observation period than did spruce seedling density.

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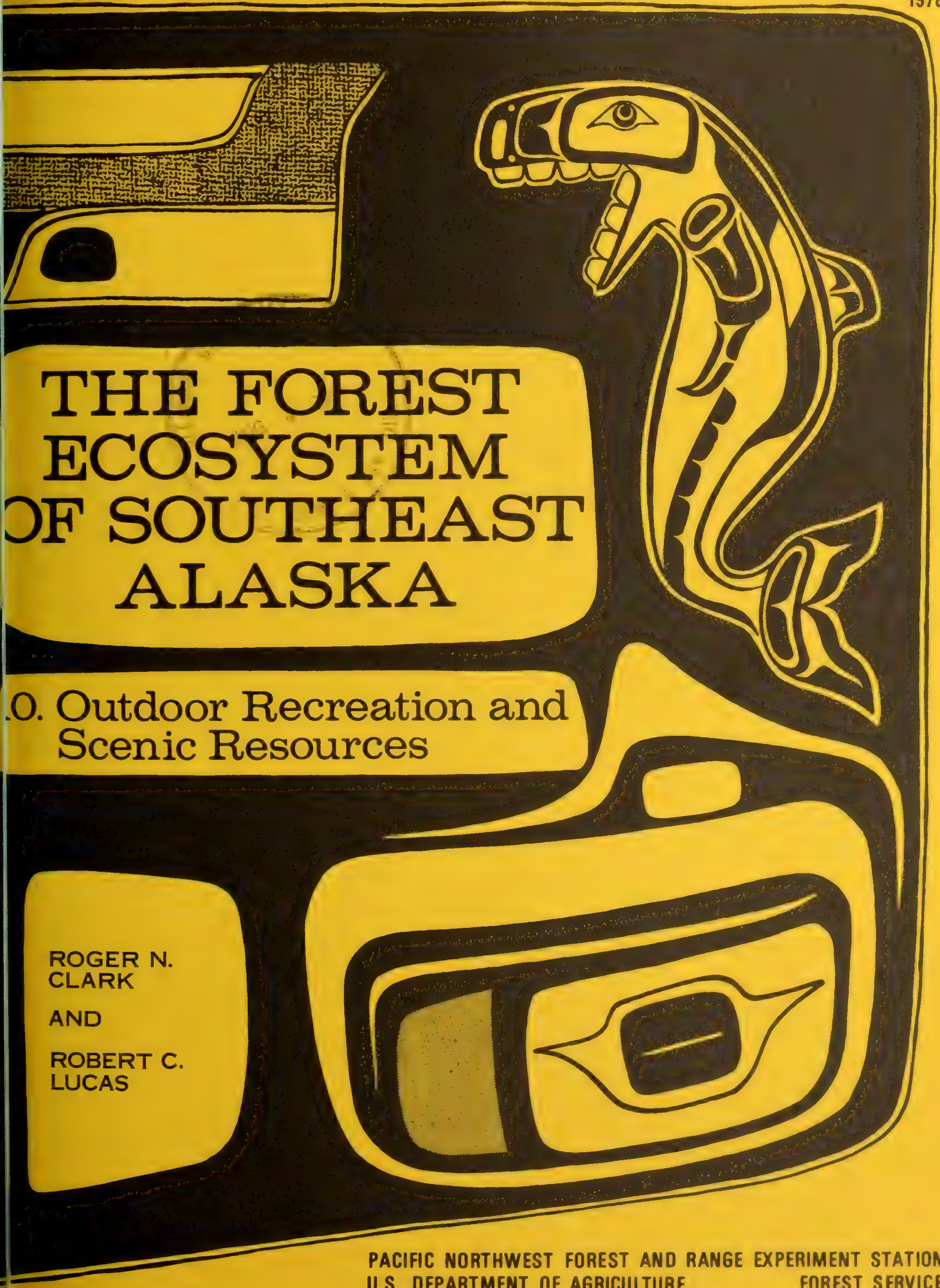

THE FOREST ECOSYSTEM OF SOUTHEAST ALASKA

0. Outdoor Recreation and Scenic Resources

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AND

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ABSTRACT

Southeast Alaska offers a variety of recreational and esthetic or scenic resources not found elsewhere in the United States. Use of these resources for commodity production and recreational purposes is increasing, which often results in conflicts. This report summarizes what is known about the recreational and esthetic resources of the region, the present and anticipated recreation uses, and the important issues concerning recreation and esthetics.

KEYWORDS: Recreation use, recreation, resources (forest), amenity values (forest), ecosystems, Alaska (southeast).

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ENGLISH AND METRIC EQUIVALENTS

1 acre = 0.4047 hectare
1 foot = 30.48 centimeters
1 inch = 2.54 centimeters
1 mile = 1.61 kilometers
1 mile per hour = 1.61 kilometers per hour
1 pound = 0.37324 kilogram
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PREFACE

This is the tenth and final paper in a series of publications summarizing knowledge about the forest resources of southeast Alaska.

Our intent in presenting the information in these publications is to provide managers and users of southeast Alaska's forest resources with the most complete information available for estimating the consequences of various management alternatives.

In this series of papers, we have summarized published and unpublished reports and data as well as the observations of resource scientists and managers developed over years of experience in southeast Alaska. These compilations will be valuable in planning future research on forest management in southeast Alaska. The extensive lists of references will serve as a bibliography on forest resources and their utilization for this part of the United States.

Previous publications in this series include:

1. The Setting
2. Forest Insects
3. Fish Habitats
4. Wildlife Habitats
5. Soil Mass Movement
6. Forest Diseases
7. Forest Ecology and Timber Management
8. Water
9. Timber Inventory, Harvesting, Marketing, and Trends

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INTRODUCTION

> . . . This is not easy country you are about to wander through. It is huge . . . There are giant waves, avalanches, thundering glaciers, savage streams, violent winds, monumental rains, and earthquakes. It is land still emerging from the Little Ice Age. New-born land, where there actually are small, dainty things to look at, but where the mood is essentially sombre, bold, austere, brooding. It is harsh land, where errors in judgment are rarely forgiven. But as always, harsh land can yield great rewards . . . .
>
> --Dave Bohn (1967)

Outdoor recreation, scenic resources, and esthetic values in southeast Alaska are a fascinating blend of resources and moods. Southeast Alaska has been described as imparting "a feeling of vastness, wilderness and solitude that is reinforced by its very low population density" (fig. 1). It has been pointed out that "many

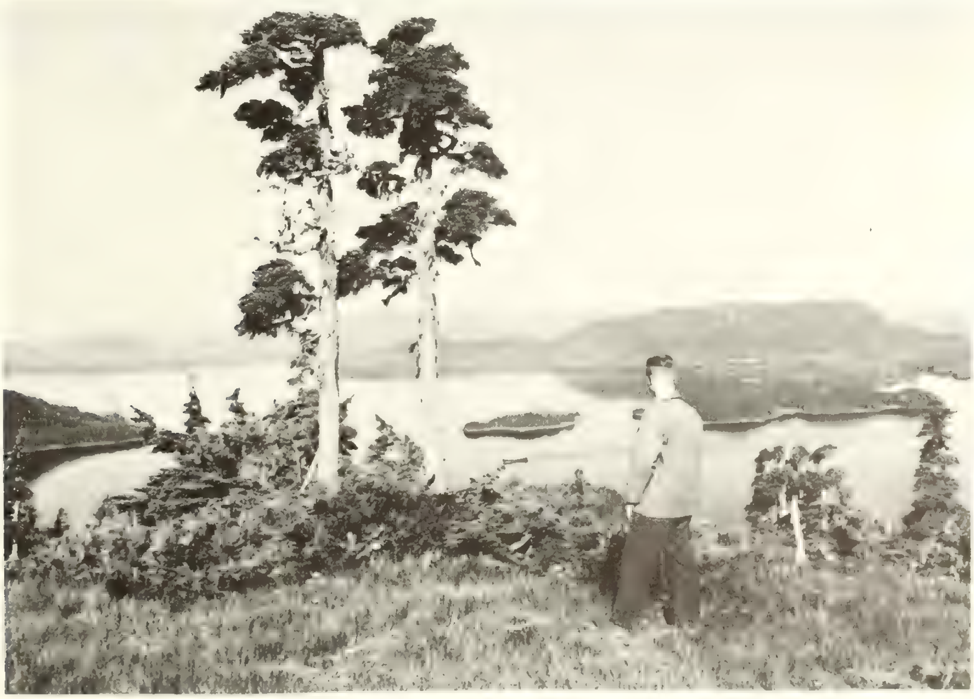

Figure 1.--Southeast Alaska has been described as relatively undeveloped, sparsely populated, water oriented, scenic, rugged, and isolated. It imparts a feeling of vastness, wilderness, and freedom. (Note the ship in center of picture, which gives a sense of the large scale of the scenery.)

perceive southeast Alaska as a reservoir of untrammeled country increasing in importance to people for their physical, mental, and spiritual well being" (USDA Forest Service 1977a). These qualities give southeast Alaska the potential to play a large and an increasingly important role in providing public outdoor recreation and scenic resource values.

SCOPE OF REPORT

This final paper in the Pacific Northwest Forest and Range Experiment Station's series on the forest ecosystem of southeast Alaska covers outdoor recreation and scenic resource values in Alaska's panhandle (fig. 2). The panhandle is located east of the 141st meridian, which runs through the Malaspina Glacier and north to the Arctic Sea. It forms a boundary between Alaska and the Yukon Territory in Canada.

PURPOSE OF REPORT

We have tried to draw together information from recent planning studies. The two major earlier assessments of the outdoor recreation situation in Alaska, the report by the Alaska Resources Committee (Cameron et al. 1938) and the report by the Conservation Foundation to the Outdoor Recreation Resources Review Commission (1962), are updated, with a narrower geographic focus on southeast Alaska. Another statewide assessment was made by Anderson in 1946. Since 1962, several other major efforts have been made to appraise this region's outdoor recreation and scenic resources, including the land use plan for the Tongass National Forest,[1] the more recent "Southeast Alaska Area Guide" (USDA Forest Service 1977a), the Joint Federal-State Land Use Planning Commission report (Resource Planning Team 1975), and the State Comprehensive Outdoor Recreation Plan (State of Alaska Department of Natural Resources 1970a, 1970b, 1970c, 1970d, 1976). The results of all these efforts as well as results from other inventories prepared by the Division of Parks in the Alaska Department of Natural Resources have been used extensively in preparing this document.

This paper will provide an overview of the current outdoor recreation and scenic resource situation and the trends in recreational opportunities and their use. Wherever existing knowledge makes it possible, management guidelines will be presented, but these will be limited and quite general. Basic descriptive information about recreational use in southeast Alaska is scarce and generally low in accuracy, and there has been too little research on outdoor recreation to support specific management guidelines. Furthermore, the setting,

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[1] Tongass National Forest Land Use Plan, 1976. Unpublished report on file at USDA Forest Service, Alaska Region, Juneau.

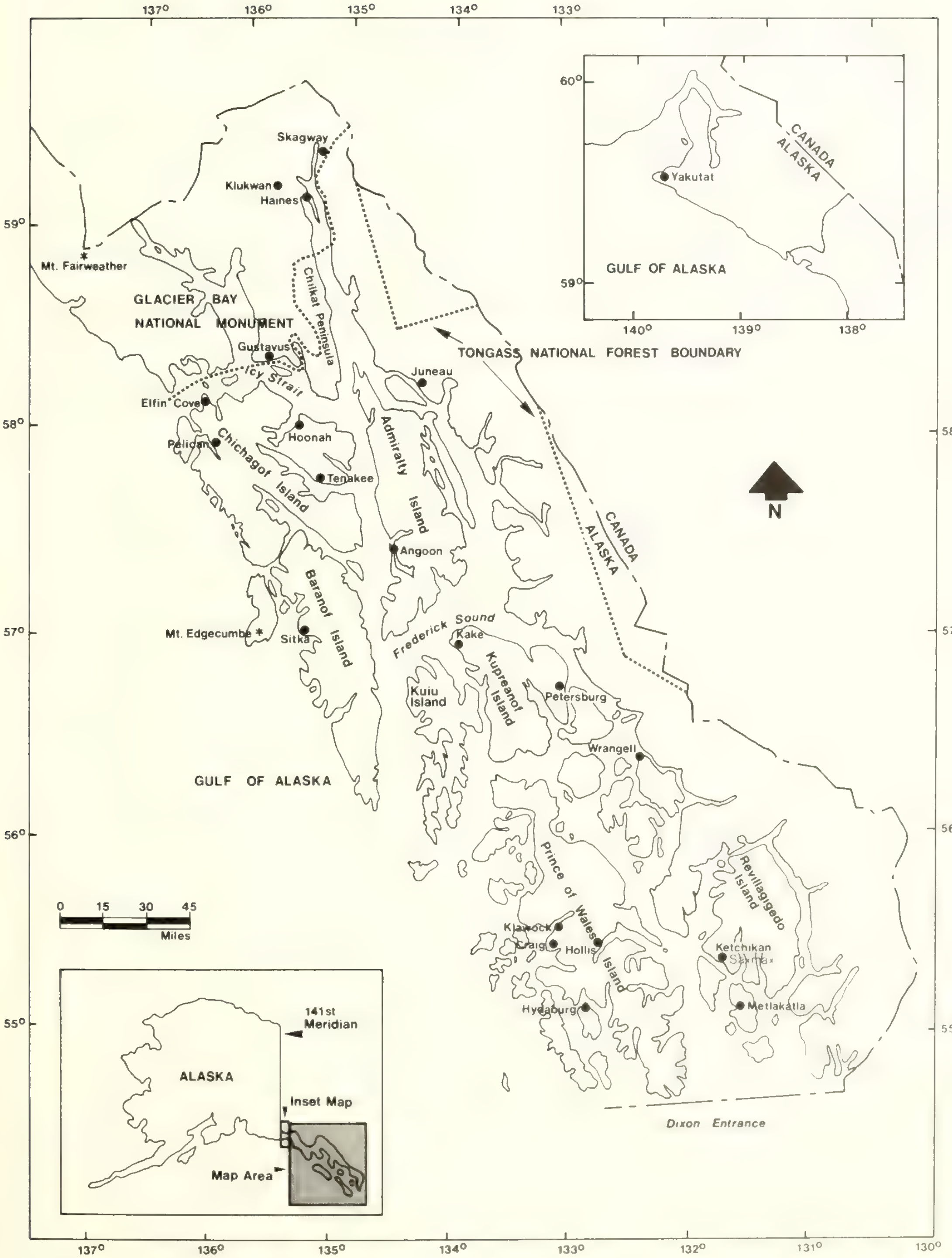

Figure 2.--Southeast Alaska.

use, and users in Alaska all differ so markedly from the areas where most outdoor recreation research has been done that applying the results of this research to southeast Alaska is risky. Research needs will be discussed briefly. Major sources of further information will be cited.

In preparing this document, we used a wide variety of sources. We found that, although there is abundant literature describing the unique recreation and scenic resources of southeast Alaska, little reliable information is available about the use of those resources. Consequently, the data presented in this report on tourism and on patterns, trends, and projections of recreation use must be used with caution for reasons we will describe later. Comments from the many reviewers of this paper (who represented a variety of professions and interests familiar with southeast Alaska) were invaluable as they often identified new sources of information or pointed out inconsistencies in the available data. Often, data from different sources are contradictory, and we have had no choice but to present conflicting figures and point out the discrepancies. These problems underscore the need for better information about recreation use in southeast Alaska. This information is valuable, however, as an initial or rough approximation of the increasing importance of this area.

SIGNIFICANCE

Southeast Alaska has long been considered exceptionally well suited for many types of recreation--particularly dispersed recreation activities such as boating, hunting, fishing, and camping under conditions of isolation, primitiveness, and scenic beauty, and also sightseeing in an unusual marine setting of forested mountains, alpine peaks, and glaciers (fig. 3). John Muir (1915, p. 15-16) naturalist and conservationist who visited southeast Alaska in the late 1800's, expressed this feeling:

> To the lover of pure wilderness Alaska is one of the most wonderful countries in the world. No excursion that I know of may be made into any other American wilderness where so marvelous an abundance of noble, newborn scenery is so charmingly brought to view.... Never before this had I been so embosomed in scenery so hopelessly beyond description.

Dispersed recreation consists of outdoor recreation opportunities characterized particularly by wide dispersion of participants and relatively limited development as contrasted to concentrated use (fig. 4).[2] Dispersed recreation is a major type of outdoor

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[2] See Lloyd, Duane R., and Virlis Fischer. Dispersed versus concentrated recreation as forest policy, 1972. Paper (speech 16) presented to the Seventh World Forestry Congress, Buenos Aires, Argentina.

Figure 3.--Southeast Alaska has long been considered exceptionally well suited for many types of dispersed recreation.

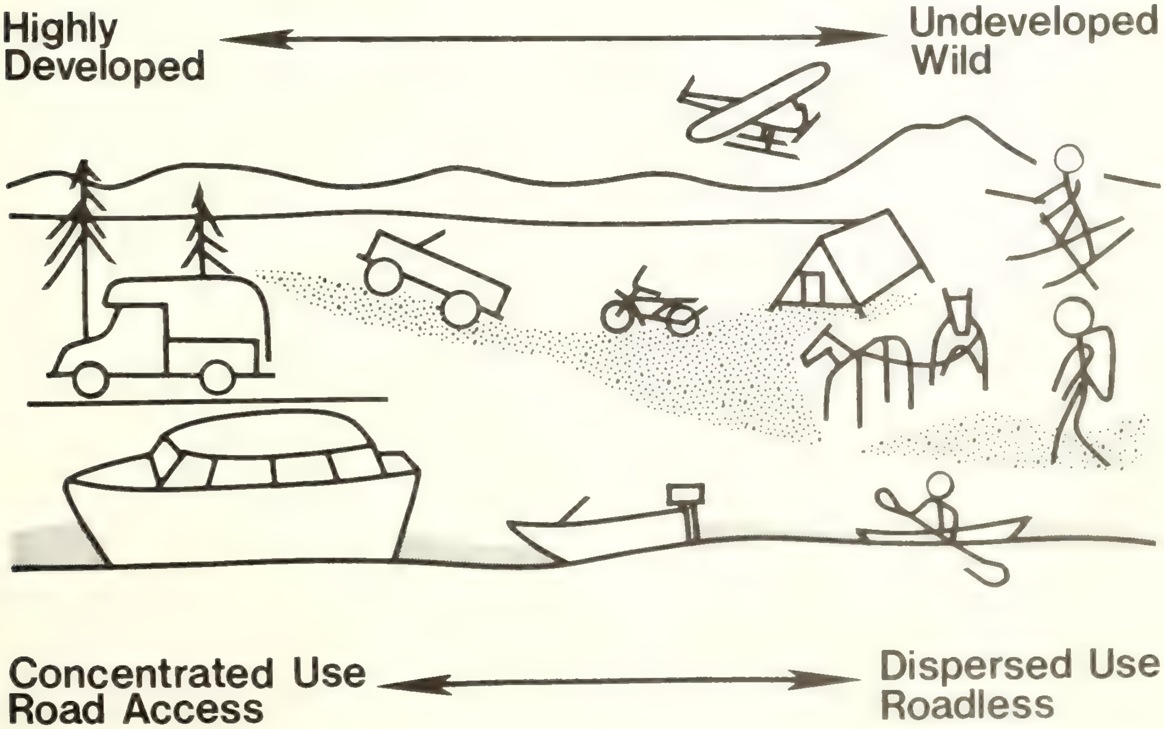


Figure 4.--The outdoor recreation opportunity spectrum.

recreation--it accounts for nearly two-thirds (64 percent) of all recreation visitor-days for the whole National Forest System of the United States--and it is growing rapidly. The program for the National Forests under the Forest and Rangeland Renewable Resources Planning Act proposes an increased relative emphasis on dispersed recreation (USDA Forest Service 1977b). Southeast Alaska is well suited to dispersed recreation as shown by the fact that about 75 percent of all National Forest recreation use in Alaska is in the dispersed categories (USDA Forest Service 1977a). Because of its relatively undeveloped character and recreational and scenic resources, southeast Alaska clearly has the potential to contribute substantially to a national program emphasizing dispersed recreation, especially some portions of the opportunity spectrum not well represented or, in some cases, nonexistent elsewhere. Certainly, however, developed forms of outdoor recreation will be important here as in other parts of the country.

Southeast Alaska is unique, or at least very different, from the rest of the United States in a number of ways that are important in terms of outdoor recreation. The area is large, and the resident population is very small. In 1974, about 50,000 people lived in an area of 42,000 square miles (almost 27 million acres). The area is about 525 miles long by 120 miles wide. Southeast Alaska is a small part of Alaska--only 7 percent of the total area. With 15 percent of Alaska's total population, it is relatively densely populated by Alaskan standards. But Alaska is so huge and lightly populated that a comparison of southeast Alaska's population density with a "lower 48" State produces a very different picture. The total area of southeast Alaska (including interisland waterways) is about the size of the State of Washington; the land area is about half the size of Washington. The population of southeast Alaska is, however, only 1-1/2 percent that of Washington. Over 20 percent of the people living in southeast Alaska are Natives, mainly Haida and Tlingit Indians, who live both in small, largely native villages and in the towns.

Unique natural and cultural features including icefields, vast expanses of primitive lands, inland waterways, glaciers, diverse fish and wildlife, plus past and present cultures set southeast Alaska apart from the rest of the country (fig. 5).

The distance from Alaska to the lower 48 States means that the distinction between tourists and local recreationists is clear; residents and tourists are two distinct groups. In contrast, in most places in the rest of the United States, there is a continuum of recreationists' residence areas ranging all the way from local to distant areas resulting in a gradual transition from local to regional to national tourist groups without sharp distinctions between them.

Because travel is oriented to water rather than to land, the transportation system is unique. Aircraft, boats, and ships are the

Figure 5.--Unique natural and cultural features including icefields, vast expanses of primitive land, inland waterways, glaciers, diverse wildlife, and past and present cultures, set southeast Alaska apart from the rest of the country. The Juneau icefield pictured here is becoming an increasingly important recreation attraction, as well as the setting for glaciological research.

main means of travel between southeast Alaska and the rest of Alaska and the lower 48 States, as well as between communities in southeast Alaska. Private boat ownership per capita is high. The highway system is minor and largely disconnected.

As a result of the air and marine transport system, much tourism involves little or no direct contact with resources and impact on them. Many visitors view the magnificent scenery, especially from the ferries and cruise ships, in a sense, almost as though they were in an "isolation booth." (Incidents of pollution of the harbors and waterways have occurred, however). Other visitors travel into the wild country and meet its challenges.

The direct impact on the land by local recreationists is also largely concentrated on the limited, more accessible locations around towns with their small, local road networks, and near good anchorages and major floatplane landing sites.

Although many residents find the primitive character of the area an important attraction, along with its superb scenery, fish and wildlife, and other recreation resources, many recreationists find conditions difficult; for example, the long winter season, heavy rainfall, dense vegetation, steep terrain, limited access except by boat, and a large population of potentially dangerous brown bear in many areas. But, just as use has mushroomed on whitewater rivers once considered too dangerous to float, the skills needed to cope with the difficulties of the Alaskan environment can be expected to grow.

Finally, the proportion of land administered by public agencies is exceptionally high (except in comparison with the rest of Alaska). The two major land managing agencies in southeast Alaska--the U.S. Forest Service and the National Park Service--administer the largest units in their agencies, the Tongass National Forest and Glacier Bay National Monument. The Tongass National Forest includes almost 16 million acres, about 60 percent of the total area of southeast Alaska. All of the communities of southeast Alaska except in the Haines-Skagway area are within the Tongass National Forest, where very little private or State land is located. The National Park Service is responsible for 2,900,000 acres, about 11 percent of the total. Other Federal and State management agencies account for most of the remainder. Problems of public access, posted private land, and so on are rare in southeast Alaska. About 500,000 acres will change jurisdiction under terms of the Alaska Native Claims Settlement Act and up to 400,000 acres under the Statehood Act, but Federal land will still account for most of the total acreage.

The economic significance of outdoor recreation and tourism in southeast Alaska clearly is substantial but it is poorly measured and cannot be specified in detail. Most of the little work that has been done to assess its significance has focused on the entire State (State of Alaska Office of the Governor 1975, Kiely and Hilpert 1961, Field Research Corporation 1976). Several of the unusual features of the southeast Alaska recreation setting have conflicting economic implications. The self-contained nature of the cruise ships and ferries probably reduces economic impacts in southeast Alaska cities. In contrast, economic impacts from other visitors may be increased because stays are usually longer than the average in the lower 48 States--most people who travel so far stay longer. The dependence on charter planes or boats, and often guides, results in large expenditures. Furthermore, some unknown proportion of the immigration to Alaska and permanent settlement there is motivated by the lure of outstanding outdoor recreation opportunities.

The "last frontier," and the resulting "second chance, and fresh start for resource planning" are often mentioned in discussions of Alaska. The area is sometimes thought of as a blank State, with the future course yet to be filled in. But for southeast Alaska, these ideas have only partial validity. Resource commitments, primarily of timber, are already substantial. In addition, there are about 10,000 mining claims. Rather than a postponement or escape from difficult resource management decisions and coordination problems, southeast Alaska presents land managers with immediate and difficult challenges to identify, manage, and protect recreation opportunities and scenic resources. Certainly options remain, and few specific details are set beyond change, but resource planning must work within complex restraints.

Two major, broad planning issues loom especially large (several others will be discussed later). First, what portion of the outdoor recreation opportunity spectrum should be emphasized in this region? What combinations of different opportunities fit the resource base and the needs of Alaskans and visiting tourists? What is a desirable mix of opportunities? A general emphasis on dispersed recreation seems strongly indicated; but more concentrated, developed areas are also needed; and the dispersed opportunities need to be defined more specifically. Second, how can commodity production be coordinated with recreation opportunities? What is the optimum balance of commodity production and protection? How can production enhance or detract least from recreation values (including fish and wildlife) and landscape esthetics?

Protection of the generally superb scenery viewed from the inland waterways is particularly important. Visitors who tour by boat may have no direct impact on the forests and lands, but the converse is not true--the forests and evidence of timber harvesting or other resource utilization in them directly affect scenic values. Resource managers face the difficult task of reconciling these two, often conflicting, values of the forest (fig. 6).

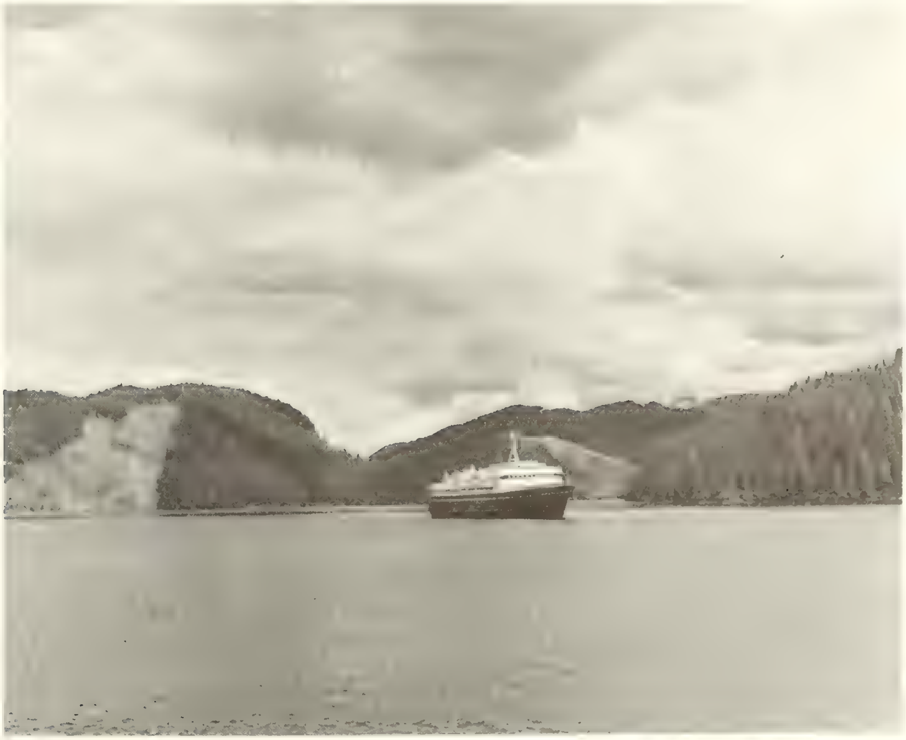


Figure 6.--The protection of superb scenery viewed from the inland waterways is particularly important. Many people are concerned about the location of clearcuts along the scenic inside passage.

THE SETTING

This section briefly describes the various resources related to the recreation potential in southeast Alaska. These resources include physical and biological features, as well as historical and cultural attractions. Present and proposed recreation developments and systems for moving residents and visitors throughout the area are discussed. Trends in resource development and implications for future recreation opportunity and demand are described.

The information in this section came from a variety of sources, much of it not published. Many Federal and State agencies have compiled a substantial amount of descriptive information regarding the recreation related resources of southeast Alaska. Some of these data are contained in a variety of land use planning documents, environmental analysis reports, and environmental impact statements. In addition to these more formal reports, information on recreation resources and opportunities is available in popular form through organizations such as the State and local chambers of commerce, the State tourism division, and other agencies which provide information services for visitors on lands they administer for recreation purposes. Although it is not the purpose of this report to identify all existing material, representative literature has been cited. The reader is also referred to a recent bibliography covering material related to recreation in all of Alaska (Muth and Fitchet 1976).

A major source for this paper has been the other reports in the series on "The Forest Ecosystem of Southeast Alaska" (Harris et al. 1974; Harris and Farr 1974; Hutchison and LaBau 1975; Meehan 1974a, 1974b; Schmiege et al. 1974). The recreation resource is unique in that it is represented by the combination of all other physical and biological resources and how they have been managed by man for his use and enjoyment. The complex interrelationships among these resources have important implications for recreation opportunities and use. This document draws heavily on the earlier resource reports, and we have extracted portions of earlier reports of this Alaska series, with slight revisions for our use here. Readers are encouraged to refer to the reports cited for more detailed descriptions of particular resources.

Henry Gannett (1904), former Chief Geographer of the Geological Survey and member of the Harriman Alaska Expedition early in this century, expressed an opinion of the Alaska scenery, particularly in the southeast, with which many people would agree:

> There is one other asset of the Territory not yet enumerated, imponderable, and difficult to appraise, yet one of the chief assets of Alaska, if not the greatest. This is the scenery. There are glaciers, mountains, fiords elsewhere, but nowhere else on earth is there such abundance and magnificence of

> mountain, fiord, and glacier scenery. For thousands of miles the coast is a continuous panorama. For the one Yosemite of California, Alaska has hundreds. The mountains and glaciers of the Cascade Range are duplicated and a thousandfold exceeded in Alaska. The Alaska coast is to become the show place of the entire earth, and pilgrims, not only from the United States, but from far beyond the seas, will throng in endless procession to see it. Its grandeur is more valuable than the gold or the fish or the timber, for it will never be exhausted. This value measured by direct returns in money returned from tourists will be enormous, measured in health and pleasure it will be incalculable.

THE MARINE ENVIRONMENT

Perhaps the most striking and unique feature of southeast Alaska is its marine setting. The area has a close affinity with the ocean; and most of man's activities, whether commercial or recreational in nature, depend on the ocean and at the same time are constrained by it. The most westerly portion of the coastline--stretching some 525 miles from northwest to southeast--faces the open seas on the Gulf of Alaska. The "wave beaten coast" label found on many maps is descriptive of the area, noted for its winter storms and rough seas (fig. 7).

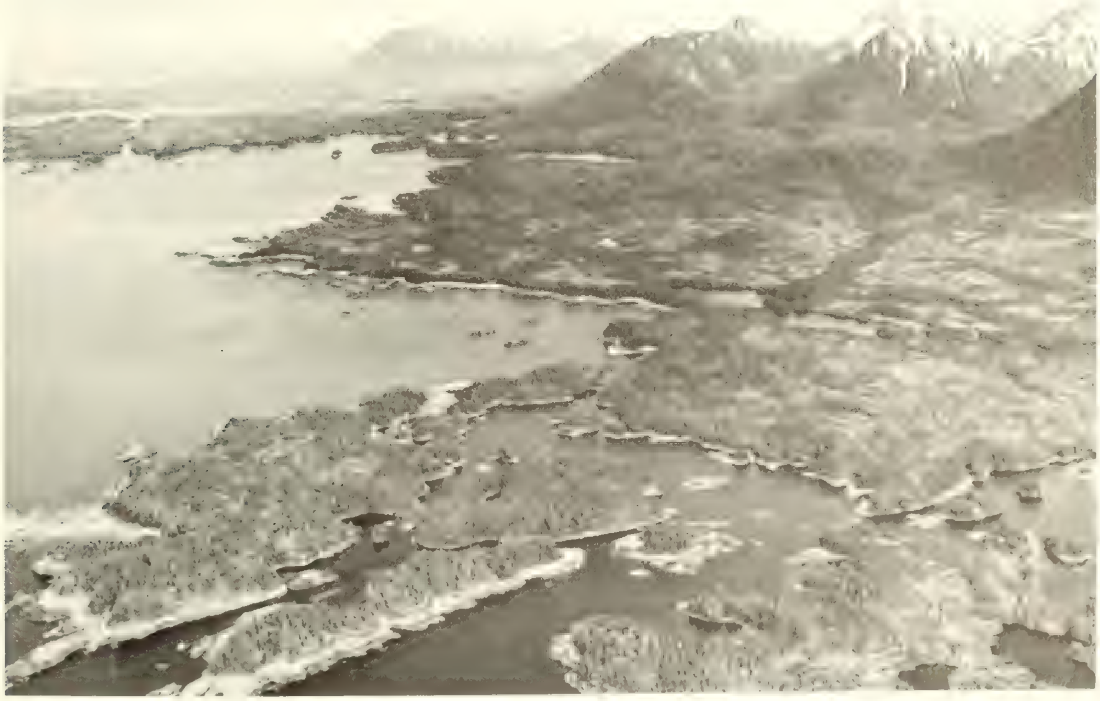


Figure 7.--The "wave beaten coast" label found on many maps describes the shoreline of the most westerly part of southeast Alaska.

Few recreational boaters spend much time in this area.

Further inland, the saltwater setting remains, but the protection provided by the hundreds of islands and broken coastline results in a more sheltered environment (fig. 8). The 1,000-mile-long "inside passage," one of the best-known waterways in North America, runs through this area and provides residents and visitors alike a relatively sheltered travel zone for viewing the many outstanding natural features of the area (Garrett 1965). For the adventurous with a desire for exploring vast expanses of wild, unpopulated country, any turn off this well-known route will lead past numerous islands, up fiords whose size and awesome beauty rival those in the Scandinavian countries, to sheltered bays, coves, and over 2,000 salmon-producing streams. Major waters with boating opportunities located away from the Alaska Marine Highway routes are shown in figure 9.

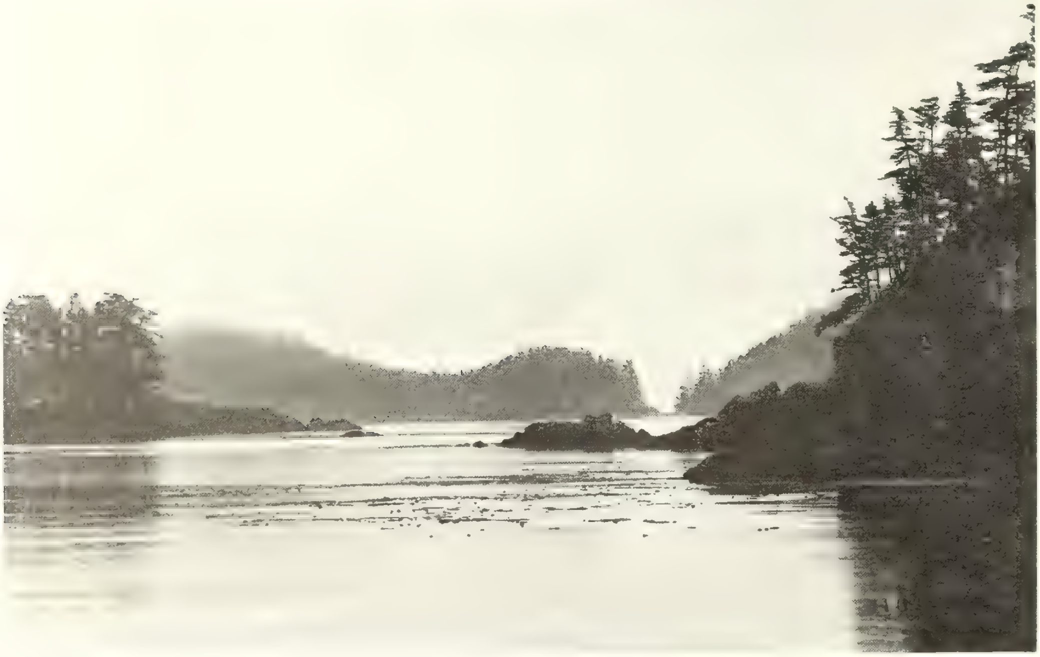
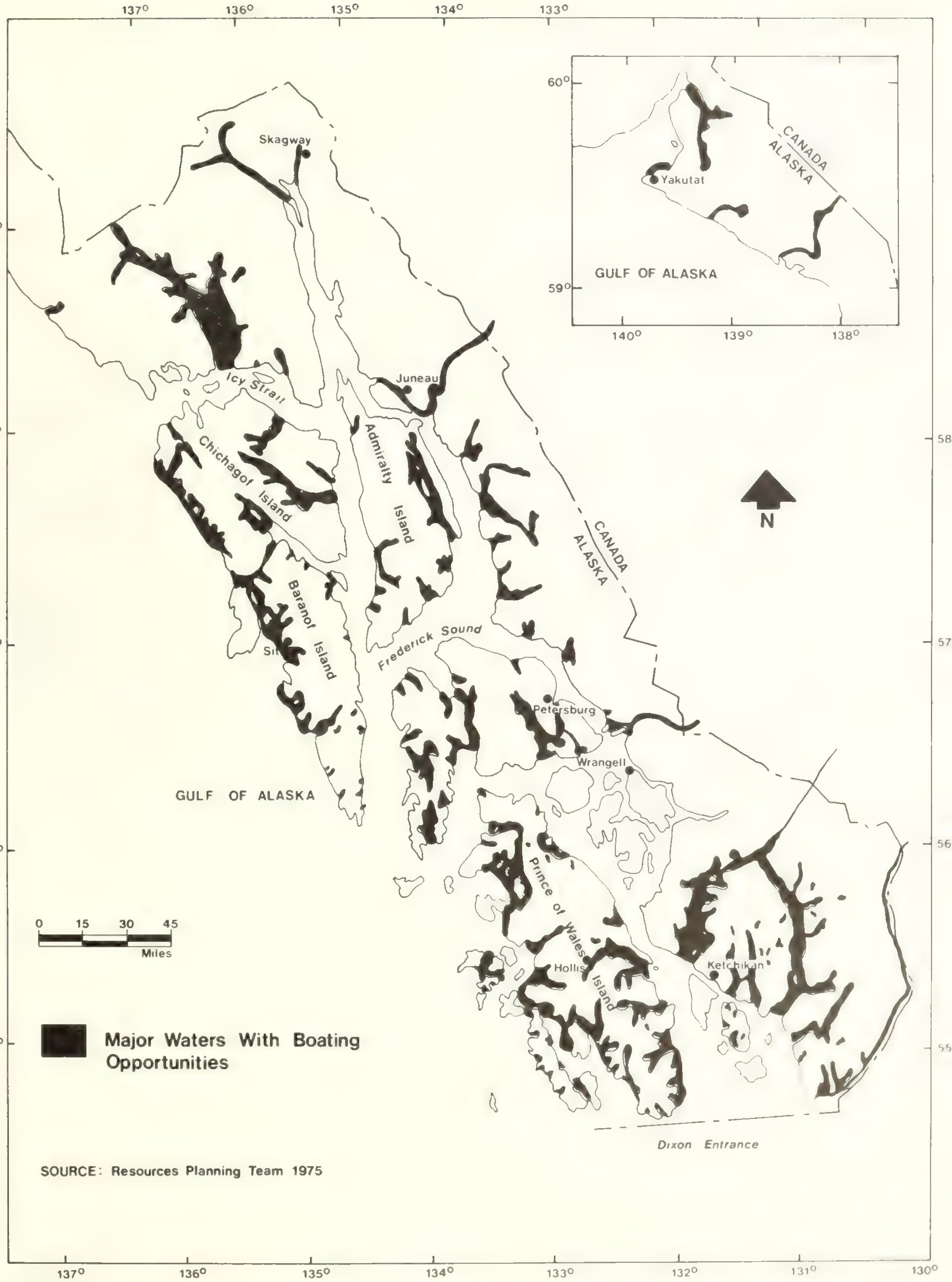


Figure 8.--Further inland, the saltwater setting remains, but the hundreds of islands and broken coastline result in a more sheltered and enclosed environment.



SOURCE: Resources Planning Team 1975

Figure 9.--Major waters with opportunity for boating in southeast Alaska. (Source: Resource Planning Team 1975.)

The appeal of the marine environment was well described by Cameron et al. (1938, p. 130) 40 years ago:

> The beauty of the mountains is accentuated and made accessible by the tongues of the sea, which have invaded the gorges, drowned the valleys, and produced an intricate system of tidal waterways. Some of these are broad expanses of water dotted with islands. Others resemble great river gorges extending far inland with great depth, restricted by beetling cliffs. Hundreds of miles of navigable channels exist.
>
> The most striking of these waterways are the gorges or fiords, of which Glacier Bay and Portland and Lynn Canals are the most notable. They extend inland for 60, 100, and 175 miles, respectively. Some sections are remarkably straight, others sinuous. For many miles they are bounded by sheer walls, rising in places to peaks 8,000 and 9,000 feet above the sea. The shores are broken in places by embayments fed by tidewater glaciers.... This type of scenery, which is one of the outstanding tourist attractions in Scandinavia, is extensively duplicated in Alaska.

For those who might mistake the apparent serenity of the area for a freshwater setting, a look at the tides is warning enough for the potential boater and beachcomber. Mean diurnal tidal fluctuations in southeast Alaska vary from 8 feet on the west coast of the archipelago to 14 feet in the inland passage; the range between extreme high tides and low tides is considerably greater, nearly 25 feet at Juneau and Skagway (Selkregg 1976). Many activities in this region are regulated by the tides.

Hundreds of islands forming the Alexander Archipelago are scattered between the outer coastal areas and the mainland to the east. Summits generally rise from 2,500 to 3,500 feet. Many islands are unnamed. They vary in size from less than an acre to more than 1,000 square miles; 65 islands exceed 4 square miles, 15 are over 100 square miles, and 6 are greater than 1,000 square miles. These six large islands (fig. 2) are: Prince of Wales (2,770 square miles); Chichagof (2,062 square miles); Admiralty (1,709 square miles); Baranof (1,636 square miles); Revillagigedo (1,134 square miles); and Kupreanof (1,084 square miles) (Harris et al. 1974). Most of the islands are unpopulated and remain undisturbed by man, and they offer ample opportunities for exploration and recreation in natural conditions.

The numerous islands, islets, and rocks are separated by a complex system of marine features such as sounds, straits, canals, narrows, and channels. The combined length of the tidal shoreline resulting from the many islands, as well as the mainland, is impressive compared with that of the lower 48 States (fig. 10).

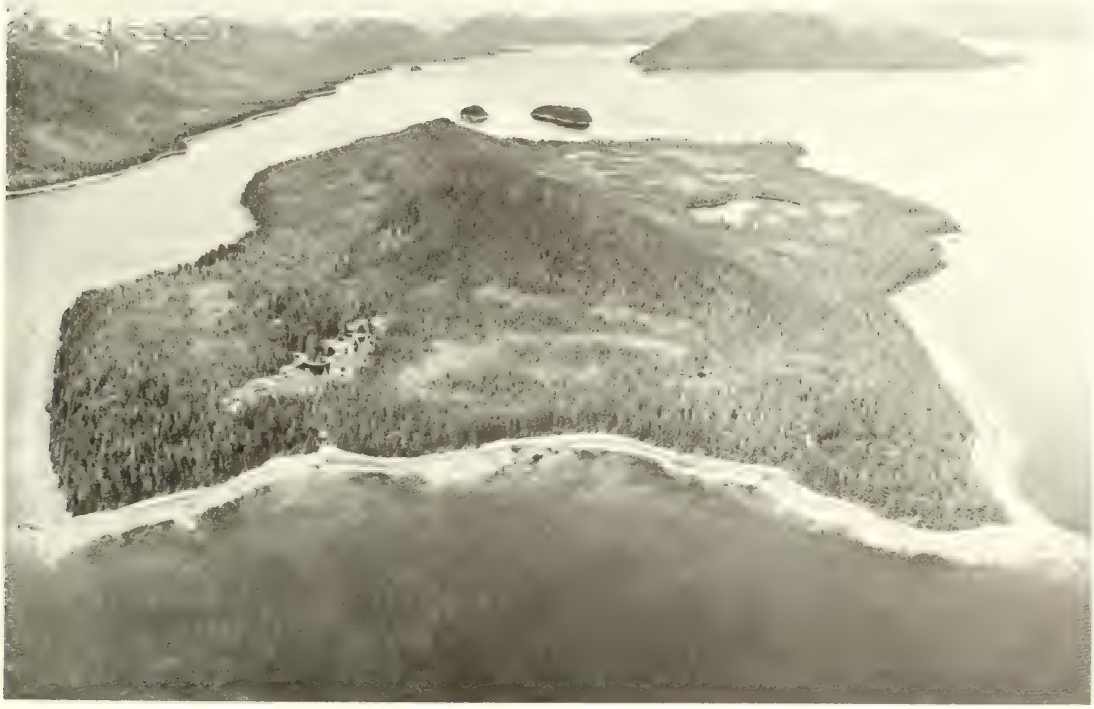


Figure 10.--The hundreds of islands are separated by sounds, canals, narrows, and channels.

Alaska proper has just over half the "general coastline" of the United States--6,640 miles (U.S. Army Corps of Engineers 1971). The tidal shoreline, including all shoreline to the head of tidewater, is much longer--estimated at over 47,000 miles in all of Alaska--with about 29,000 miles of intricate coastline in southeast Alaska. For the most part, the coastline is rocky and steep; but there are many accessible stretches, including beaches located in the hundreds of sheltered inlets, bays, arms, coves, harbors, and anchorages. These areas are important recreation attractions and may require special management decisions to insure their protection. The larger tidal inlets and estuarine areas are important feeding and resting areas for waterfowl in the spring and fall, especially the Stikine River estuary.

CLIMATE[3]

Much of the character of southeast Alaska comes from its climate; the icefields and glaciers, dense vegetation, huge trees, large salmon runs, and abundant wildlife result from a combination of weather factors. Southeast Alaska's climate is maritime--cool and moist. The temperature range is narrow, and moisture is abundant. The overall effects are cool summers, moderate winters, heavy precipitation well distributed throughout the year, heavy snowfall at higher elevations resulting in large numbers of glaciers and several icefields, and a high incidence of fog and cloudiness. All these climatic features have important effects on resource uses and management, including recreation.

Temperatures usually range from 60°F to 70°F during the summer and rarely drop below -10°F during the winter. The climate has been described as only slightly harsher than Seattle, Washington, or Vancouver, B.C. (Resource Planning Team 1975); but some residents disagree, citing fewer growing degree days (Harris 1974) and longer winter darkness in southeast Alaska.

Although it is south of the "land of the midnight sun," southeast Alaska is far enough north to experience a wide range of daily hours of light during the year (Selkregg 1976). This reduces daily temperature fluctuations (Watson et al. 1971) and provides more daylight hours for outdoor activities during the summer. Daylight throughout the latitudes of southeast Alaska ranges from about 18-1/2 hours in June to as little as 7 hours in December. Twilight during the summer materially lengthens the day to more than 20 hours.

The other major temperature effect is the moderating influence of the open waters of the inland passages. These waters are warmed by the circulation of the Alaska current, and their temperatures range from about 55°F in the summer to about 42°F in the winter. The coast is generally free of ice.

Precipitation generally accumulates to between 60 and 200 inches as steady, light to moderate rain or snow during about 200 to 250 days in the year. Extreme values for annual precipitation means are 26 inches at Skagway and 200 inches at Little Port Walter (Selkregg 1976). Maximum monthly rainfall ranges from 10 inches at Skagway to almost 60 inches at Little Port Walter. Cloudy skies occur on 275 days; 43 days are clear, and the remainder are partly cloudy. The likelihood of lasting snow during the winter increases from south to north.

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[3] For a more detailed description of southeast Alaska's climate, see Harris et al. (1974) and Selkregg (1976).

The prominent low pressure systems, called Aleutian Lows, make southeast Alaska a stormy area, both winter and summer. A normal storm track along the Aleutian Island chain, the Alaska Peninsula, and all the coastal area of the Gulf of Alaska exposes these areas to most of the storms crossing the North Pacific (Searby 1968). The resultant nearly constant east-west zonal circulation dominates throughout autumn and winter and intermittently at other times of the year (Marcus 1964). The Coast Mountains backing southeastern Alaska effectively interrupt the surface atmospheric circulation (Fitton 1930) and usually cut off artic air masses. But, at times, Canadian or arctic high pressure systems spill over the Coast Mountains, bringing strong northerly winds which gust through the long marine valleys. "Taku" winds, blowing across the Juneau icefield, have been reported at more than 200 miles per hour. This windiness has taken a toll of merchant and fishing vessels and has done considerable structural damage to buildings, electric transmission line towers, and so on. It poses an ever present threat to recreational boaters and fliers along the outer coast and in the inland waters as well. "Weather is the factor inhibiting this region as a perfect vacation spot. Visitors must recognize that they may experience many rainy, cool, and cloudy days, and that they may not wish to participate actively in outdoor recreation activities unless they have special equipment and accommodations. The relatively heavy use of 'live aboard' vessels in southeastern Alaska is evidence of the effect of the climate upon recreation patterns" (State of Alaska Department of Natural Resources 1970b). A more recent survey indicates Alaska's weather is a negative factor in the mind of many past and potential visitors (Field Research Corporation 1976).

MOUNTAINS[4]

The mountains of southeast Alaska afford varied and spectacular scenery. Their rugged slopes challenge hikers and climbers. Many of the larger mountain ranges rise directly from the sea. The topography includes parts of the two high-mountain systems. The eastern range along the boundary with Canada consists mainly of the mountains associated with the Coast Range--the extension of the Cascades in Washington and Coast Mountains in British Columbia. Elevations of peaks along the boundary range are from 6,000 to 10,000 feet, with most of the main peaks between 7,000 and 9,000 feet.

Mount Fairweather rises to 15,300 feet; Mount St. Elias, the highest point (18,008 feet) in the southeast Alaska system, is the fourth highest peak in North America (Atwood 1940). Areas of subdued relief are uncommon in southeast Alaska except for the comparatively low islands that make up the southern part of the Alexander Archipelago.

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[4] Much of the material in this section was taken from Harris et al. (1974).

GLACIERS AND ICEFIELDS

Among the most spectacular natural features of southeast Alaska are the numerous glaciers, many of which extend into saltwater before melting. Extensive glaciation was and is a major factor in the formation of the rugged mountains of the region. Icefields are nearly continuous along the coast range of the mainland and from these flow many active glaciers. The largest glacier, the Malaspina, located at the northernmost portion of the southeast region and covering more than 1,000 square miles, flows to the sea from the mountains of Canada.

One of the most spectacular and often visited areas in southeast Alaska is Glacier Bay National Monument, 75 miles northwest of Juneau, which has more than 20 active glaciers, some flowing into saltwater (Streveler and Paige 1971). Muir Glacier, the most famous, measures nearly 2 miles across and rises about 265 feet above the waterline. Observers are often able to see nature in action as massive walls of ice up to 200 feet high fall into the water, thereby forming oceanborne icebergs, a process known as "calving" (fig. 11).

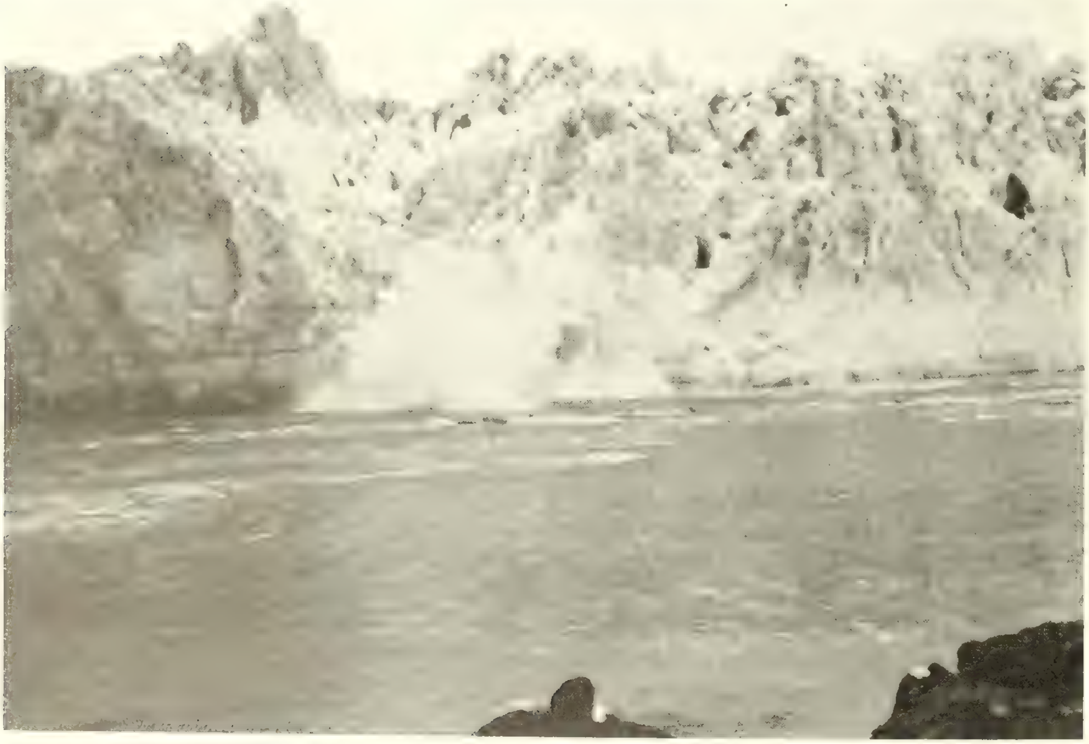

Figure 11.--Observers are often able to see nature in action as massive walls of ice (about 200 feet high in this photo) fall into the water and form icebergs.

Residents and visitors to Juneau can easily visit the Mendenhall Glacier flowing from the Juneau icefield above the city (fig. 12). The area is within a few miles of the city and is accessible by paved road. An interpretive center and a nature trail along the flanks of the glacier are featured. The Mendenhall is a year-round attraction for local residents and tourists alike.

LeConte Glacier near Petersburg is the southernmost glacier entering saltwater in Alaska. It is visited by many persons using charter boats and airplanes. Glaciers are also visible from the Alaska Marine Highway near Haines, Skagway, and Wrangell.

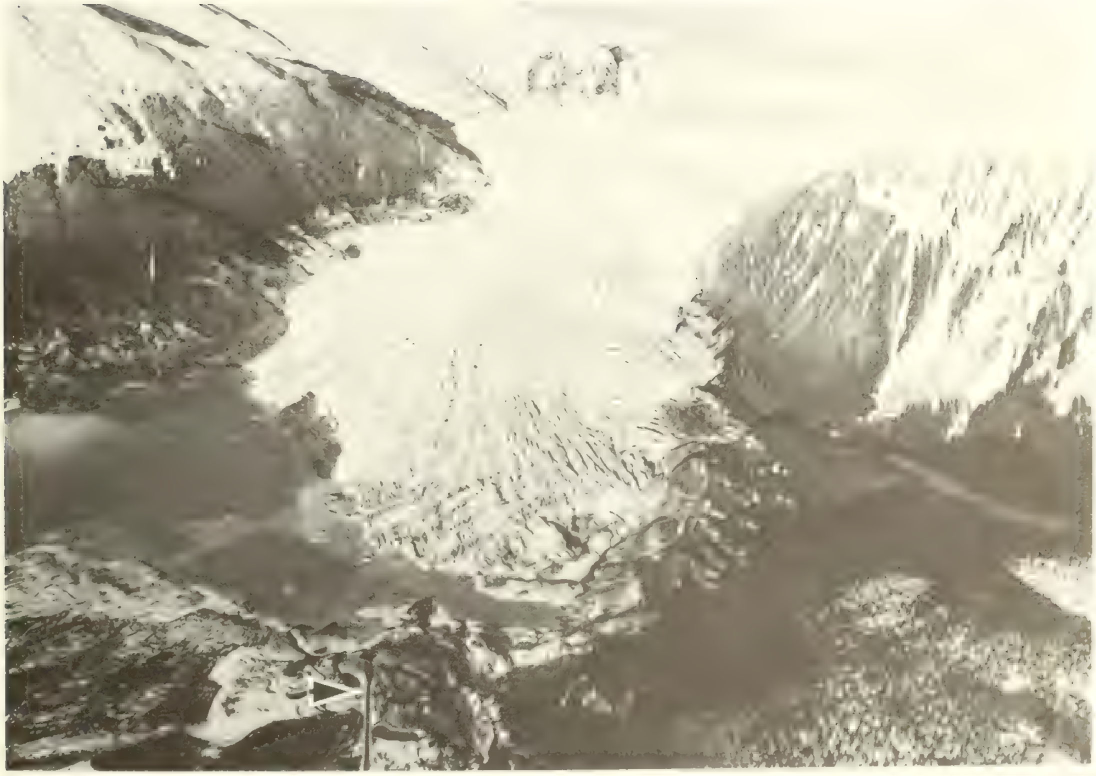

Figure 12.--Residents of and visitors to Juneau can easily visit the Mendenhall Glacier which flows from the icefield above the city of Juneau. The arrow indicates the road leading to the Mendenhall Glacier visitor center and viewpoint.

FRESH WATER RESOURCES—LAKES AND STREAMS

For people seeking recreational experiences on or near freshwater, southeast Alaska offers abundant opportunities in the form of hundreds of lakes and thousands of streams, most of which flow into saltwater. Much of the water in the lakes, streams, ponds, marshes, and estuaries of southeast Alaska still remains unaltered by man's activities (Schmiege et al. 1974).

Major rivers in southeast Alaska originate in the mountains of Canada (Harris et al. 1974). The principal rivers are the Alsek, Chilkat, Chickamin, Taku, Whiting, Stikine, and Unuk. Other important mainland rivers include the Salmon, Klehine, Bradfield, Speel, and Taiya Rivers. Some of the islands have important streams, such as Thorne River on Prince of Wales Island. Many of the rivers are large enough for canoes and kayaks, and a few carry larger power boats. In an inventory of streams in the Alaska region, some 2,634 streams were identified in southeast Alaska totaling nearly 6,000 miles.[5] These data indicate the streams are relatively short; they typically fall sharply, often with beautiful waterfalls, and many are glacier fed (fig. 13). Although few of these smaller streams offer opportunities for boating, the streams are an important esthetic resource and many offer excellent fishing.

In addition to the ocean and the streams, many lakes are found in this region, on both the mainland and the islands (fig. 14). Nearly 600 natural lakes, totaling more than 120,000 acres, have been identified. They vary in size from a few acres to several thousand acres and in type from coastal marsh to high alpine cirque lakes (Resource Planning Team 1975). Some of the larger, more accessible lakes afford opportunities for powerboating and sailing. Others remain inaccessible except by floatplane.

More than 100 hot springs are found throughout southeast Alaska. Several are well known and facilities have been built to accommodate use by a growing number of recreationists.

Twenty-six manmade impoundments for hydroelectric power have also been developed in southeast Alaska, and applications for more are pending. Most are small--their combined size is only a little over 3,600 acres. Although fishing and boating are reported on some, the significance of these areas from a recreation perspective is not known. It is unlikely that they will receive the amount and kind of use that similar projects in the lower 48 States would receive because of the abundance of natural lakes and saltwater opportunities in southeast Alaska.

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[5] Source: U.S. Forest Service files, 1971, summary data on lakes and streams, Alaska Region, Juneau.

Figure 13.--Most of the over 2,000 streams are fairly short and fall sharply.

Figure 14.--In addition to the ocean and streams, nearly 600 lakes are found in this region, on both the mainland and the islands.

VEGETATION[6]

A notable feature of southeast Alaska is the lush plant life. Except for steep cliffs, few areas are devoid of vegetation. Here, even rock, which would be bare in a drier climate, is soon colonized by mosses, lichens, small plants, shrubs, or trees. This vegetation offers tremendous potential for esthetic, recreational, and educational purposes.

The forest of southeast Alaska is a segment of the temperate rain forest extending along the Pacific coast from northern California to Cook Inlet in Alaska. Viewed from a boat, the rugged mountains along the inside passage usually appear to be carpeted with unbroken conifer forests from the water to timberline. From the air, however, the forest zone is seen as a mosaic of forest stands of various densities, crown sizes, and subtly varying colors, interspersed with numerous muskeg openings.

Forests cover about 11 million acres of southeast Alaska (USDA Forest Service 1977a). Most of the forest is old growth (more than 150 years old), undisturbed by man. Stands which have remained undisturbed for centuries have a ragged texture because they include trees of various ages, sizes, and conditions, with many dead tops and snags. Stands disturbed during the last century or two by windthrow, fire, landslides, or logging have a more uniform appearance because they contain trees of relatively uniform age and size, with fewer snags and less damage. Moss covers everything and often drapes from the trees.

The distribution of trees varies by location (Hutchison 1967). The islands to the south and west are more heavily covered with large, more continuous forests. There are also large stands on the mainland and in the north, but these are restricted to stringers and patches near salt water and valley bottoms.

Tree species composition also varies by location. The most important trees on commercial forest lands are western hemlock, Sitka spruce, western redcedar, Alaska-cedar, mountain hemlock, and other softwoods, black cottonwood, red alder, and other hardwoods. Species composition of trees on land classified as noncommercial forest land consists largely of hemlocks, cedars, and shore pine.

Interspersed with forest stands are natural openings, often hidden from view on the water but prominent from the air. These are muskegs or bog plant communities. Muskegs are usually on flat or gently sloping topography, but they develop on steeper slopes as well.

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[6] Much of the material in this section was taken from Harris et al. (1974) and Harris and Farr (1974).

They provide suitable habitat for many plants with edible berries and give welcome scenic viewpoints for the foot traveler, as well as valuable scenic diversity for the airborne or waterborne traveler. Muskegs are also important as habitat for wildlife, especially deer and bear.

Between the muskegs and dense forest are more open forest stands presently classed as noncommercial or scrub stands. The open canopy allows sufficient light to reach the forest floor to support dense understory vegetation of blueberry, huckleberry, rusty menziesia, other tall shrubs, and numerous small vascular plants. These stands are important wildlife habitat and potential sites for berrypicking.

Tidal flats are found at the heads of numerous bays and inlets. They are usually associated with stream estuaries and are occupied by grasses, sedges, rushes, and numerous other plants. In addition to their scenic beauty, they provide habitat for wildlife, especially bear and waterfowl, as well as clams and other shellfish.

Above timberline which varies from 1,000 to 3,000 feet (Harris 1974), the alpine zone is dominated by heaths, grasses, and other low plants. Beautiful wildflowers abound in season. Plants such as deer cabbage cover wide areas and provide excellent summer forage for deer. Occasional trees occur, often with stunted or shrublike form because of adverse growing conditions. Timberline generally varies in elevation from 3,000 feet in the south to 2,500 feet in the north but may be depressed because of differences in climate, topography, and other factors which influence accumulation, retention, and avalanching of snow. The alpine area provides many fine recreation and scenic opportunities, but access is often difficult because of dense timber and brush (including thorn-studded devils club) from the shoreline to timberline. Brown bear often frequent the alpine zone during summer and fall.

For the interested forest visitor, several excellent sources of detailed information are available for the identification and distribution of trees and other plants native to southeast Alaska. For trees and shrubs, "Alaska Trees and Shrubs" (Viereck and Little 1972) is the best reference. This is a revised and expanded edition of "Pocket-Guide to Alaska Trees" (Taylor and Little 1950), which is still useful. A comprehensive text on the flora of the area by Hultén (1968) includes keys to all vascular plants known to occur in the area.

Botanical interests in southeast Alaska include plant succession after glacial retreat and recently exposed remains of trees buried by past glacial deposition (Resource Planning Team 1975).

Because most forest stands of commercial quality are located near tidewater and along stream and river valleys (all of which are main travel corridors) confined to relatively low elevations (generally below 2,000 feet (Harris 1974)), they are valuable not only for their timber resource but also for recreation, esthetics, and protection of other resources. This single fact has led to an important conflict in values which, although not unique to southeast Alaska, seems particularly pronounced there.

Use of no other resource in southeast Alaska has such important implications for recreation and esthetic values as the harvesting of timber. Later we will discuss this conflict in more detail. Here, to put the amount of harvest in perspective, we briefly describe the extent of man's use of the timber resource. Table 1 summarizes the distribution of commercial and noncommercial forest lands in this region and the amount of land undisturbed at present. Figure 15 shows the growth in timber harvest since 1917. These data indicate the proportion of total land area available for commercial timber harvest (36 percent). About one-third of the National Forest land is of commercial value, and 2 percent of that has been reserved or withdrawn as research natural areas and wilderness study areas. About 3 percent of the commercial forest land (143,000 acres) has been logged since 1965. (This is only an estimate since actual acreages have never been determined.) But even this amount of timber cutting has important impacts on the scenic resource of southeast

Table 1--*Classification of Tongass National Forest Lands*[1/]

Classification	Number of acres (approximate)	Approximate percent of National Forest land
Total land in southeast Alaska	26,900,000	--
Total National Forest lands[2]	16,000,000	100
Forested area:		
Commercial forest land	5,800,000	36
Productive forest land deferred or reserved from harvest	300,000	2
Noncommercial forest land[2]	4,500,000	28
Nonforested	5,400,000	34
National Forest roadless area (undeveloped) as of 1972[3]	14,030,000	87
Wilderness study area	1,900,000	12
Cutover since 1972[2]	65,000	0.4

[1] Lands outside the Tongass National Forest are excluded because of lack of information. However, virtually all forested lands of southeast Alaska (about 11 million acres) are within the Tongass National Forest.

[2] National Forest timber inventory data. This estimate is based on an estimate of the volume of timber per acre. No actual acreage measurements have been done.

[3] Based on results from the USDA Forest Service roadless area review study (RARE) completed in 1972, Washington, D.C.

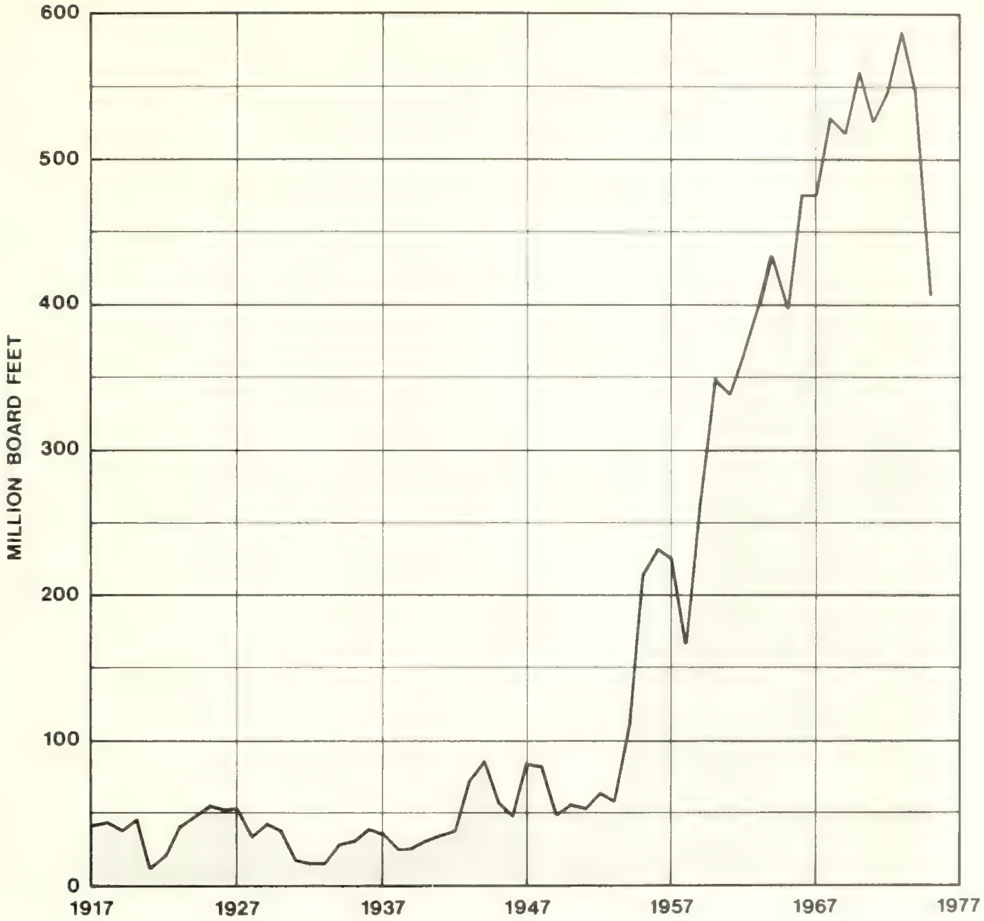

Figure 15.--Volume of timber commercially cut on National Forests of southeast Alaska by year.

Alaska and on those forms of outdoor recreation dependent on natural conditions. These impacts are intensified because most logged-over areas are on the waterways or within view of them and form an important part of the scenic foreground. These impacts are certain to increase as the timber becomes increasingly important in U.S. and world markets.

As a result of timber harvest activities, opportunities for road-oriented recreation and easy access to upland areas are increased. In some areas (Admiralty Island, for example), these opportunities are being identified for potential users.

FISHERIES[7]

Southeast Alaska has rich recreational fisheries--including saltwater, freshwater, and anadromous species (State of Alaska Department of Fish and Game 1972) and an abundance of shellfish including the famous Alaska king crab--as well as major commercial fisheries.

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[7] Much of the material for this section was taken from Resource Planning Team (1975).

A variety of species are available on the open sea, in protected marine waterways, on major rivers, along small streams, or in the many lakes (fig. 16). Southeast Alaska is one of the few regions in the country where an intensive stocking program is not yet necessary to support a recreational fishery, although this might depend on light use because some accessible areas near larger towns have suffered severe declines in fish populations as a result of heavy fishing.

Figure 16.--A variety of species of fish are available in the deep sea, in protected marine waterways, on major rivers, along stream, or in the many lakes.

Anadromous fish--those spending part of their life in freshwater and part in saltwater--are present throughout the area. Pink (humpback or humpy), coho (silver), and chum (dog) salmon spawn in the shorter coastal streams. Sockeye (red) salmon are found in river systems containing lakes. Chinook (king) salmon[8] are located in the longer river systems of the mainland, some of which extend into Canadian territory. Another spawning area for Chinook is in the aptly named King Salmon River on Admiralty Island. Steelhead and resident rainbow trout are present in many places, and cutthroat trout and Dolly Varden (char) are found throughout the entire area. Eastern brook trout have been planted and have established themselves in several lake systems.

Besides fish entering freshwater, herring, halibut, rockfish, and sablefish live in adjacent saltwaters; and an abundance of shellfish are available for commercial and sport harvest. Various species of crabs, shrimp, clams, and scallops are present throughout the area.

The main species of fish caught in southeast Alaska are rainbow-steelhead, cutthroat trout, Dolly Varden, halibut, and the five species of salmon. Saltwater fishing in southeast Alaska has been some of the best in the State and certainly ranks high in comparison with other areas of the country. Recent declines in fish populations have resulted in closures and reduced bag limits, however. Numbers of pink salmon are down greatly from previous abundance. Salmon derbies are held, or have been held, in many communities including Juneau, Ketchikan, Sitka, Haines, Petersburg, Craig, Wrangell, and Kake. All harbors in the area have large sport boat fishing fleets. Freshwater fishing for either anadromous or resident species is also rated good by most residents and visitors. Dolly Varden, including some large fish, are caught in good numbers, and steelhead fishing in some areas is a major attraction for the serious angler.

Besides sport fishing, the salmon in southeast Alaska are available in larger quantities under subsistence permits, and many southeast Alaska residents fill their freezers with salmon during spawning runs each year. Outings for this purpose are often a satisfying recreational acitivity for the entire family.

Although many visitors to southeast Alaska would find fishing opportunities superlative in most areas, the Alaska Department of Fish and Game staff located in Juneau has identified some prime locations. Their inventory lists numerous drainages that they felt have outstanding sport fish values, and they recommended to the Forest Service that many of these should be kept in a natural condition to preserve these qualities.

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[8] All five species of salmon have two common names in Alaska.

WILDLIFE[9]

Wildlife is one of the first things that come to mind when people think of Alaska. This is not surprising since most films and magazine articles feature Alaskan wildlife. The State supports an extraordinary collection of birds and mammals, and southeast Alaska is no exception. The many species of wildlife afford opportunities for recreationists to bag trophies with a gun or camera. Southeast Alaska is home for a wide variety of both rare and common animals and birds ranging in size from small shrews to immense brown bears on land, to gigantic whales living in coastal and inland saltwaters. But distribution of the various species is often uneven, which results in disappointment for many sightseers expecting bears, whales, and moose at every turn. Some of the important features of this resource are described below.

Birds

More than 200 species of birds, ranging from the common to the unique, are found in southeast Alaska. Waterfowl are plentiful in many areas, including Stikine flats, Yakutat forelands, Duncan Canal, Rocky Pass, and numerous other flats at the heads of bays. A variety of species of ducks and several species of geese migrate through the area. Trumpeter swans are known to winter in a few lake and stream systems. Several species of grouse are found in some locations in southeast Alaska (Meehan 1974b). Alaska boasts the largest concentration of bald eagles in the 50 States; indeed, it has more eagles than all other States combined, and most of these are found in southeast Alaska (Robards and Taylor n.d.). A 1967 survey estimated the breeding population of bald eagles in southeast Alaska as exceeding 8,000. Although bald eagles are found throughout the area, one of the largest concentrations occurs around the shoreline of Admiralty Island with an average of two nests per mile (fig. 17). Other spectacular locations include the Chilkat River near Haines, the Stikine River during smelt runs, and the rivers of Berners Bay. Although southeast Alaska residents may find eagles commonplace, visitors to the area are in for a treat as eagles usually can be seen perched in trees, sitting on rocks along beaches, or soaring on the winds (Robards and Taylor n.d.) (fig. 18). Their nesting habitats--along saltwater shorelines and mainland rivers--correspond to man's major travel zones, which increases the probability of sightings.

Mammals

Numerous mammal species are found in the mainland, island, and saltwater environs of southeast Alaska. Their distribution varies

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[9] Important sources for this section include the Tongass Land Use Plan, an unpublished report on file at USDA Forest Service, Alaska Region, Juneau, Alaska, Resource Planning Team (1975), and Meehan (1974b).

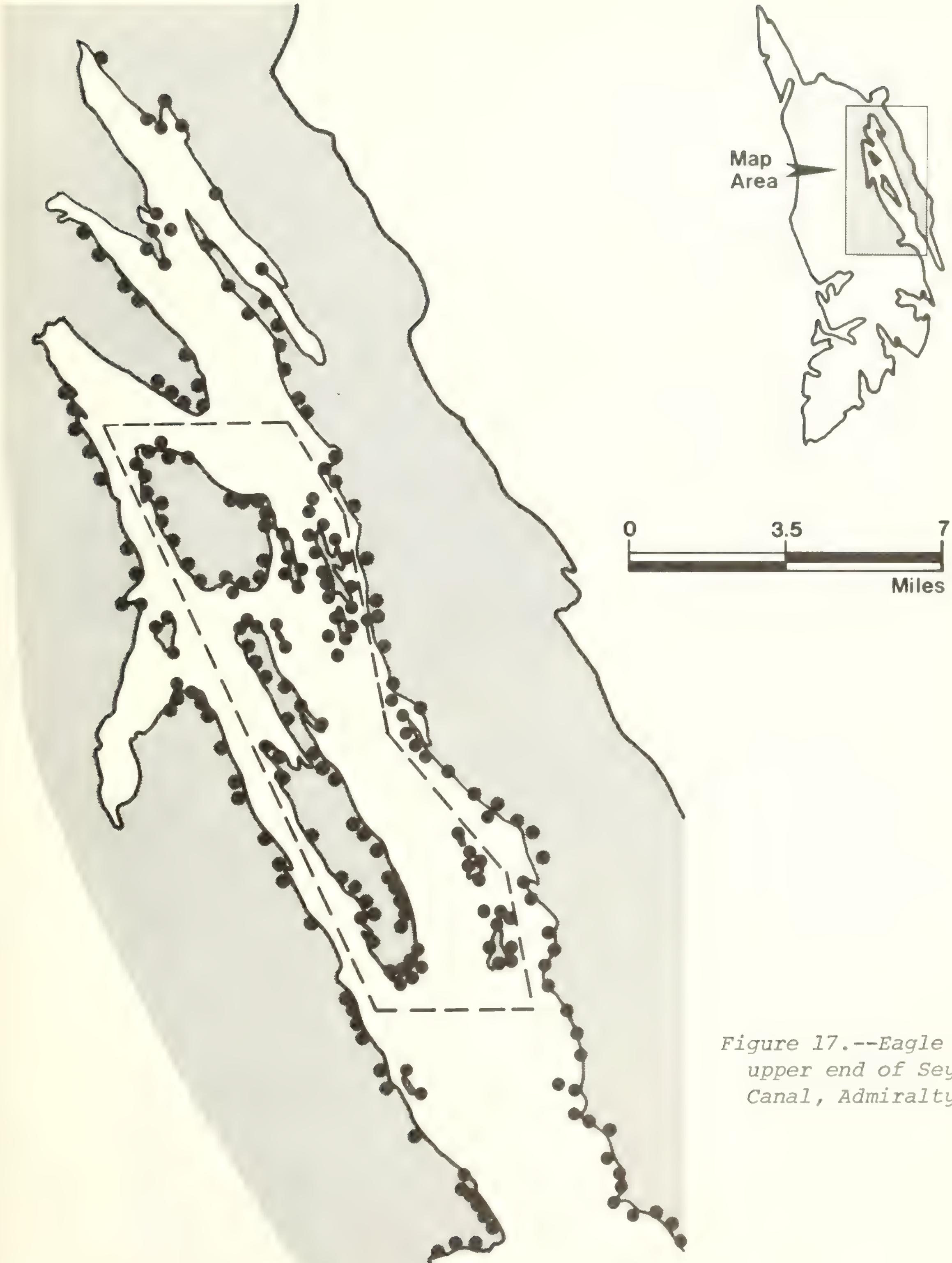

Figure 17.--Eagle nests in upper end of Seymour Canal, Admiralty Island.

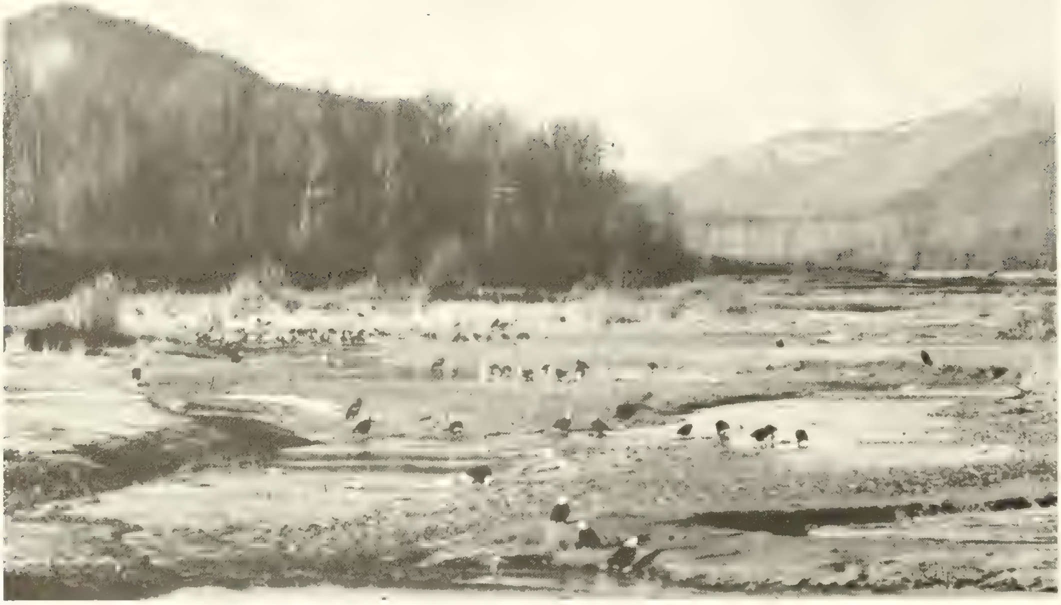

Figure 18.--Alaska has more eagles than all other States combined and most of these are found in southeast Alaska.

from mainland to the islands. Black bear are common to abundant throughout the region, except on the Admiralty, Baranof, Chichagof Islands group (the "A.B.C." group) where they are absent. Glacier bears (the blue color phase of the black bear) are found in the Russell Fiord and Disenchantment Bay areas near Yakutat.

Brown bear (fig. 19) are present throughout southeast Alaska except on the islands south of the A.B.C. group. Highest densities are on the A.B.C. islands. These bears are huge, impressive animals--often reaching 9 feet or more in length.

Wolves are present in the Yakutat area and elsewhere, common on the mainland, present on the southernmost islands, but absent on the A.B.C. islands. The Sitka black-tailed deer is a principal prey species.

Wolverine are rare on the mainland, Kuiu, and Kupreanof Islands and have not been reported on A.B.C. and Prince of Wales Islands.

Sitka black-tailed deer (fig. 20) live throughout the region and are the most common big game animal. Highest densities are on the A.B.C. islands. Deer in the Yakutat Bay area stem from a 1934 transplant.

Figure 19.--Brown bear are present throughout most of southeast Alaska. They often reach 9 feet or more in length and weigh as much as 1,400 pounds.

Figure 20.--Sitka black-tail deer are the most common big game animal found throughout southeast Alaska.

Moose are found mainly in the larger river drainages of the mainland (fig. 21). Distinct populations exist at Haines, Berners Bay (introduced), Taku River, Thomas Bay, Stikine River, and on the Yakutat forelands. A population estimate for the Yakutat area is about 4,000 to 5,000 moose. Several cabins and airstrips have been built by the Forest Service in the Yakutat area mainly for use by hunters.

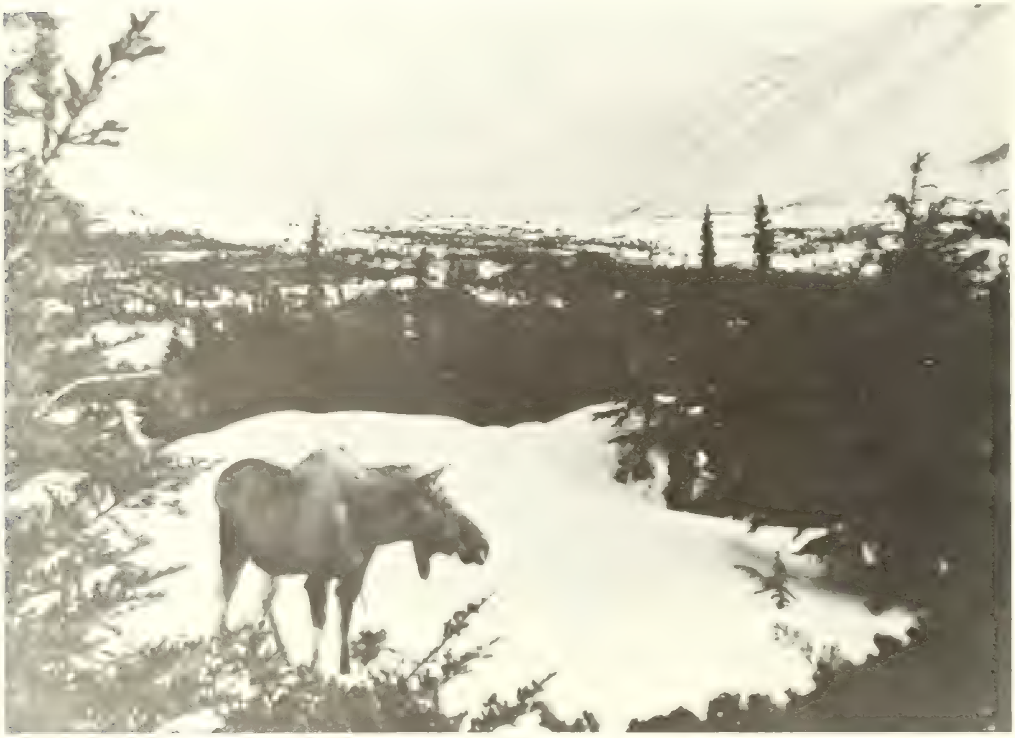

Figure 21.--Moose are confined to larger river drainages of the mainland. Several cabins and airstrips have been built by the U.S. Forest Service for hunter use.

Mountain goat live primarily on the mainland and on Baranof Island (where they were introduced). The mainland coast supports a large goat population, with many reaching trophy size.

Marine mammals inhabit most southeast Alaska waters (fig. 22). Sea otter are found along the outer coasts of the islands and the mainland area near Yakutat. Elephant seal, harbor seal, Steller's sea lion, and various whales ply most southeastern Alaska waters.

Other mammals present in certain locales are lynx, coyote, red fox, land otter, mink, marten, short-tailed weasel, fisher, beaver, muskrat, snowshoe hare, red squirrels, flying squirrels, mice, shrews, and porcupines.

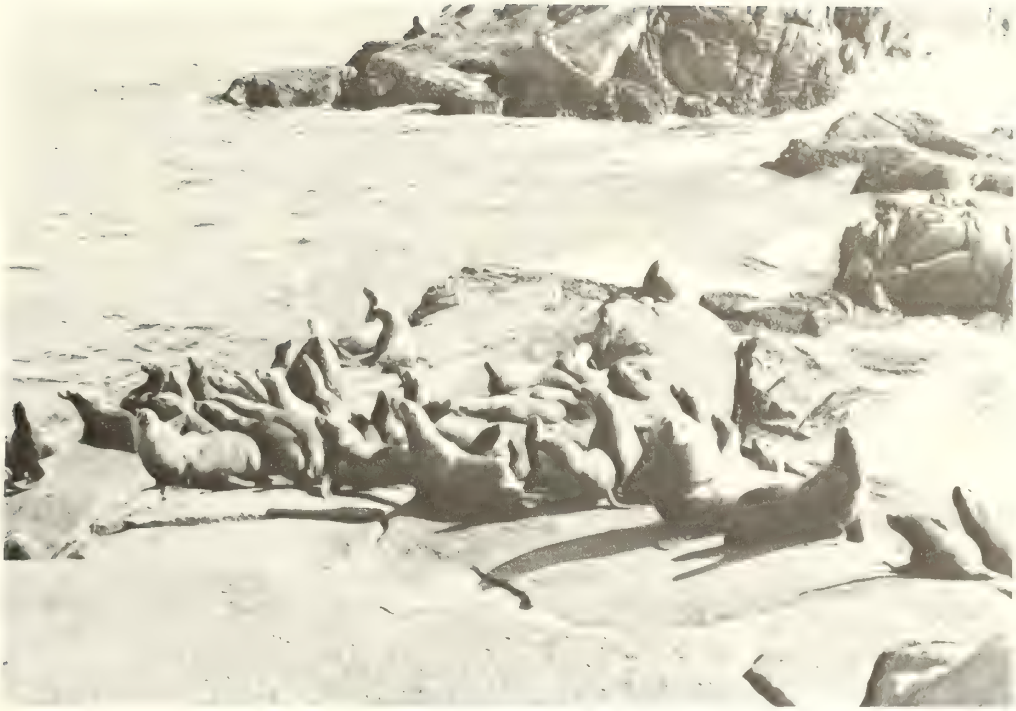

Figure 22.--Marine mammals swim most of southeast Alaska's saltwaters.

Opportunities for wildlife viewing are good whether one is driving, boating, flying, or hiking. Although many Alaskan residents are often treated to wildlife in their own backyards, visitors and residents alike can see the wide array of species in their natural state. A brown bear observatory has been built at Pack Creek on Admiralty Island where it is possible to safely watch these huge animals in their natural, undisturbed environment.

HISTORICAL-ARCHEOLOGICAL-CULTURAL RESOURCES[10]

Since man first set foot on Alaska during the Ice Age,[11] he has left an impressive record of his many activities. Both Indian and European settlers' history and culture are preserved in many places in southeast Alaska (Dixon and Johnson 1973). Only a small part of this resource is available for public viewing in museums or onsite.

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[10] Important sources for this section include Resource Planning Team (1975), Harris et al. (1974), and the proposed draft of the recreation section for the Alaska State Recreation Plan (on file at the State of Alaska Department of Natural Resources, Division of Parks, Juneau, Alaska).

[11] Estimates of when this migration occurred vary from about 10,000 to 100,000 years ago.

Examples of Native art, including the famous totems (fig. 23), are found in many locations, as well as some of the Indian split cedar long houses built years ago. The Tlingit and Haida people were considered to have one of the most highly developed cultures in North America. Remnants of tools used for fishing and hunting, as well as canoes, are found in museums, especially the State museum in Juneau. Some totem poles have been moved by the U.S. Forest Service and Indian groups to protect them from vandalism and weathering (Ciesielski 1975). The Native Sealaska Corporation reports that hundreds of historical and cemetery sites have been inventoried in southeast Alaska. These sites with their many precious artifacts are a threatened resource until their preservation is assured, as required by the antiquities act (U.S. Congress 1906).

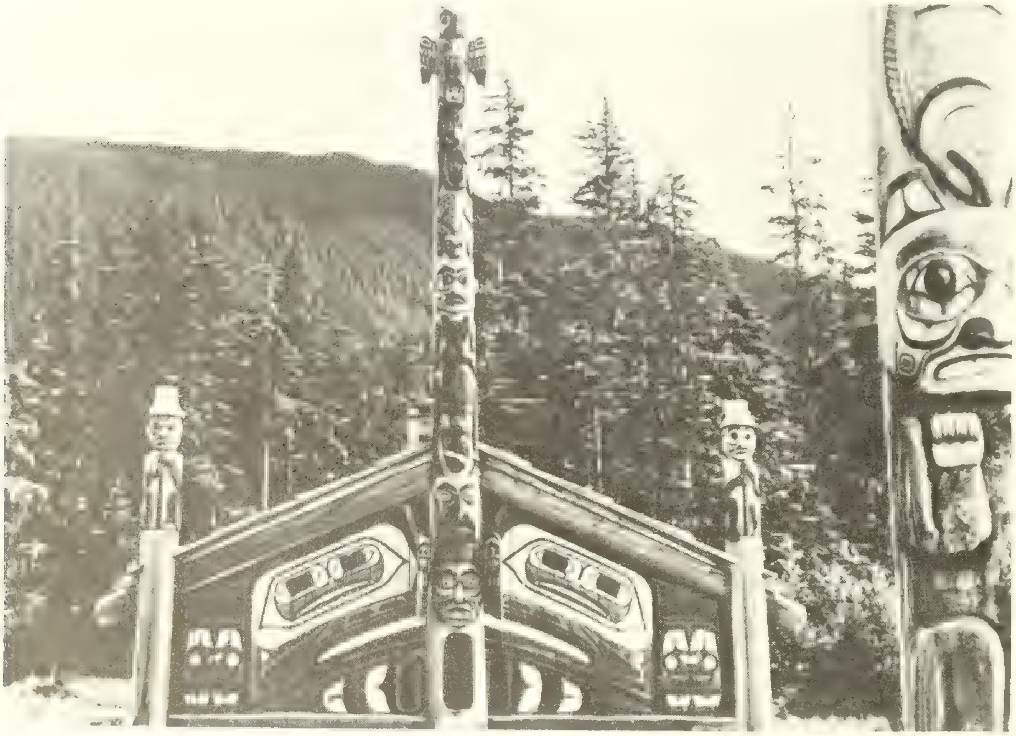

Figure 23.--Examples of Native art, including totems and split cedar long houses, are found in many places, including Totem Bight Historic Site, a State Park in Ketchikan.

European man's record in southeast Alaska began with Russian exploration in the 1700's (State of Alaska Department of Commerce and Economic Development n.d.). Following this initial contact, waves of natural resource exploitation brought Russian settlers and eventually American settlers in search of sea otter and fur seal pelts, whales, fish, gold, and timber. All these settlers have left their own identifiable mark in many forms. Potential attractions include old trails, ghost towns, mines, canneries, whaling stations, fox farms, and old logging camps. Many of these abandoned sites are complete with equipment left behind as people moved on in search of other riches because the local supply was depleted or markets collapsed.

The cultural and historical richness of southeast Alaska is affirmed by the high concentration of sites that have received national recognition. Nearly 40 percent of all Alaskan entries on the National Register of Historic Places are found in the southeast region (fig. 24).

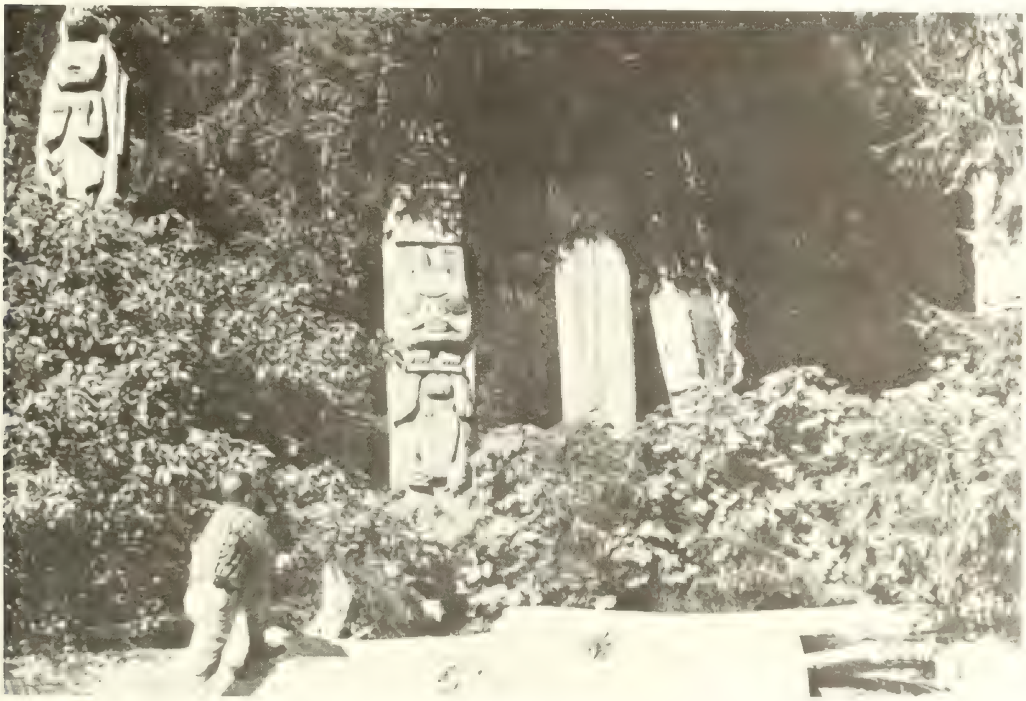

Figure 24.--The cultural and historical richness of southeast Alaska is affirmed by the high concentration of sites that have achieved national significance. This site, as well as many others, is a reminder of this region's dynamic past.

Representation of the Tlingit-Haida culture is found at Chief Shakes Island at Wrangell and Totem Bight at Ketchikan, as well as in the smaller Native villages. The Russian occupation is commemorated at places including the Baranov Castle Hill Site in Sitka, the New Russia Archaeological Site near Yakutat, St. Nicholas' Russian Orthodox Church at Juneau, and the Russian Mission Orphanage and St. Michael's Cathedral in Sitka. Days of the Klondike Gold Rush are relived in the original structures in the Skagway Historic District, and in the White Pass and Chilkoot Trails (all now part of the Klondike Gold Rush National Historical Park), Dalton Trail, and Pleasant Camp. Other cultural or historical sites include the Alaska Native Brotherhood Halls found in several communities, the American Flag Raising Site and Sheldon Jackson Museum--both at Sitka, Father Duncan's Cottage at Metlakatla, the old Alaska-Juneau Mine at Juneau, Fort William H. Seward at Fort Chilkoot, and the White Pass and Yukon

Railroad. In addition to these and other entries on the National Register, there are hundreds of cultural sites, historic places, and special events such as the Chilkoot Dancers and melodramas which enhance the present for residents and visitors alike by reminding them of this region's dynamic past. Efforts are currently underway to identify and preserve other heritage resources (State of Alaska Department of Natural Resources 1975).

In addition to man's past in southeast Alaska, his present lifestyles and activities offer an exciting and diverse opportunity for visitors to observe modern cultures at work and play. Many visitors have a chance to experience this local color while visiting towns or passing through the area by pleasure boat, ferry, or tour ship. Modern economic activities such as canneries (fig. 25),

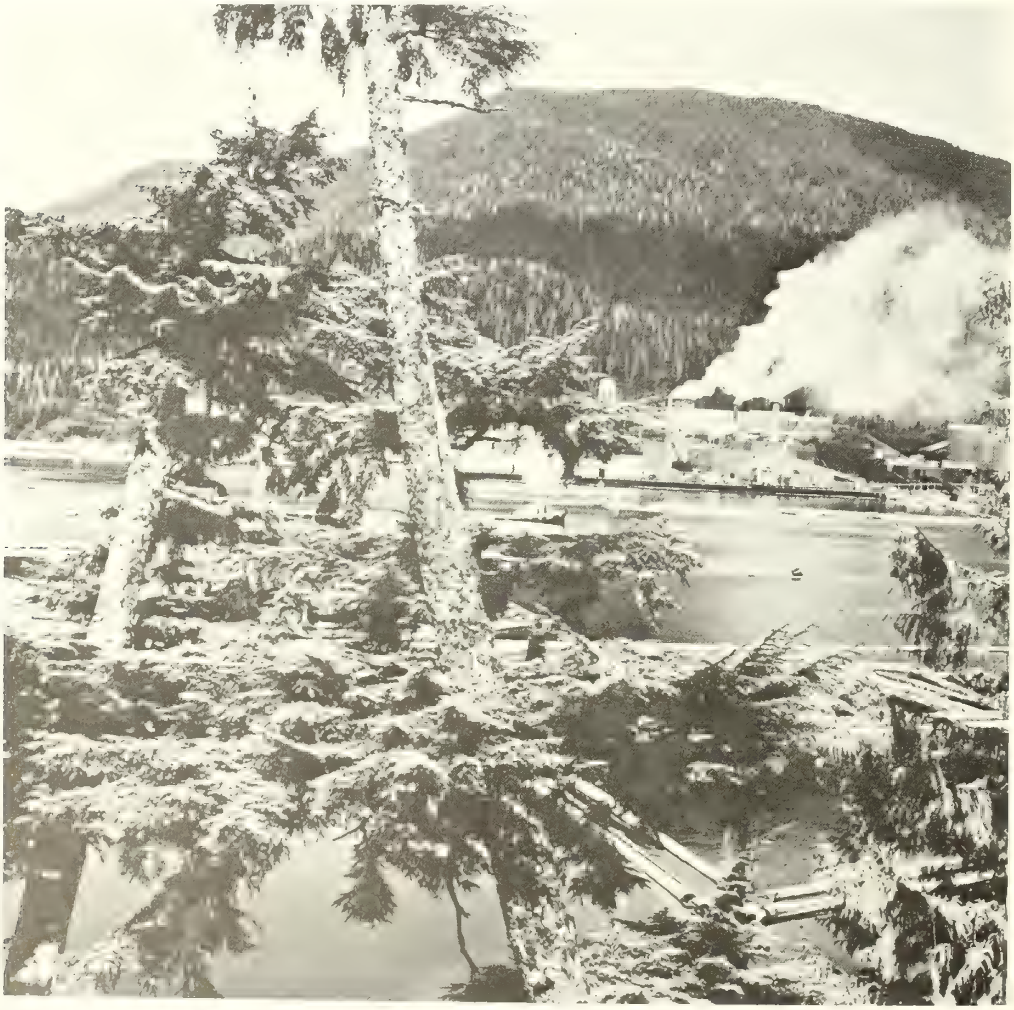

Figure 25.--Canneries, fishing boats, and mills such as this one at Ketchikan are potential recreational attractions.

fishing boats, paper and lumber mills, and logging operations can be potential recreation resources for viewing by southeast Alaskan visitors, especially if well described and interpreted.

POPULATION AND TRANSPORTATION

Potential recreationists for southeast Alaska include several distinct groups, local residents composed of whites and Native Indians, other Alaskans, and visitors from "outside," mostly from the "lower 48."

The small resident population in southeast Alaska (50,000 people) is fairly widely distributed in small cities, towns, and villages, resulting in some dispersal of the use of recreation resources by residents. The location of major communities is shown in figure 2, and the population for major towns, villages, and logging camps is shown in table 2. All the settlements and almost all the outlying

Table 2--*Resident population of selected southeast Alaska communities*[1]

Town	Native	Nonnative	Total
Angoon (74)	400	25	425
Annette Island (74)	4	396	400
Corner Bay (73)	0	57	57
Craig (74)	181	276	457
Elfin Cove (75)	0	55	55
Excursion Inlet (75)	0	300	300
Flat Creek (75)	4	57	61
Gustavus (75)	0	70	70
Haines-Port Chilkoot (74)	350	1,253	1,603
Hanus Bay	0	75	75
Hoonah (75)	720	80	800
Hydaburg (75)	370	30	400
Hyder			
Juneau (74)	2,600	14,400	17,000
Kake (75)	550	25	575
Kasaan (76)	25	8	33
Ketchikan-Saxman (74)	1,506	8,535	10,041
Klawock (76)	227	18	245
Klukwan (74)	106	4	110
LaBouchere Bay (76)	5	100	105
Metlakatla (76)	1,000	100	1,100
Meyers Chuck (76)	0	48	48
Neets Bay (76)	0	75	75
North Whale Pass (75)	10	265	275
North Shoal Cove and Coon (76)	1	100	101
Ole Creek (75)			
Pelican (75)	56	127	183
Petersburg (76)	500	1,500	2,000
Point Baker-Protection (76)	3	122	125
Port Alexander (75)	5	40	45
Port Alice (76)	[illegible]	50	50
Roosevelt Harbor (75)	0	74	74
Rowan Bay (75)	0	150	150
Sitka-Mount Edgecombe (75)	2,250	5,250	7,500
Skagway (74)	30	670	700
St. Johns Harbor (75)	0	164	164
Tenakee Springs (75)	7	94	101
Thorne Bay (76)	[illegible]	500	500
Wadleigh Bay (75)	0	40	40
Wrangell (74)	600	2,400	3,000
Yakutat (74)	325	125	450

[1] Recent population estimates compiled by the Alaska Public Health Service. Numbers in parentheses indicate year for which statistics are current.

Population figures given are maximums for summer logging, canning, and fishing seasons; winter population may decline to near zero in some locations.

residences are located next to saltwater, facilitating boating and access to all the marine types of recreation. Most towns, Juneau (fig. 26) and Ketchikan in particular, are crowded between mountains

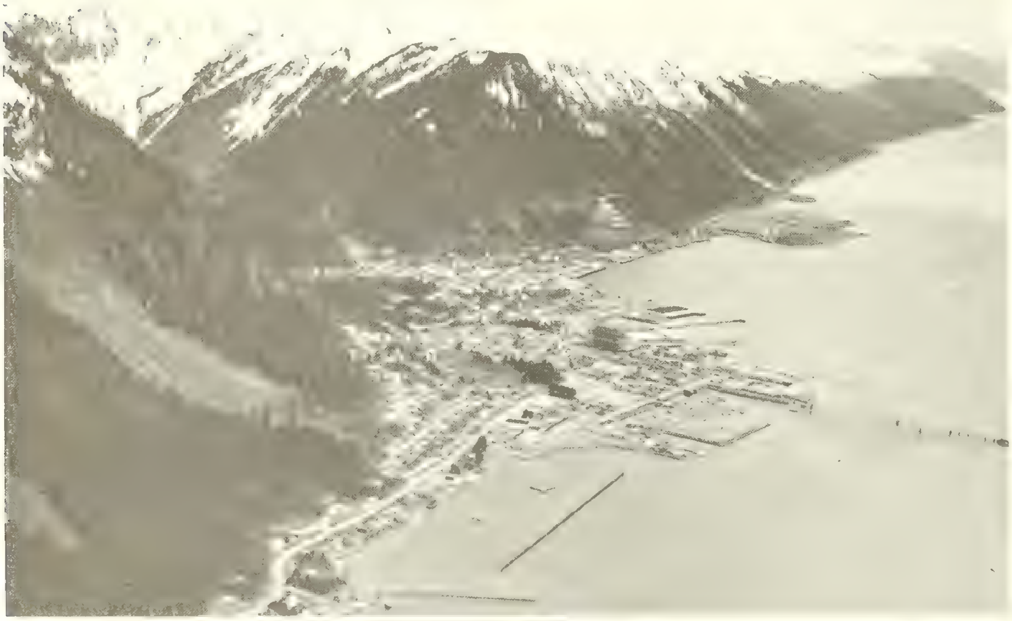

Figure 26.--Several southeast Alaska towns such as Juneau are crowded between mountains and water on narrow strips of land.

and water on narrow strips of land. A large part of the abundant shoreline is within 50 miles of the main towns.

Juneau, the State capital, is the largest city with 17,000 inhabitants in 1974. Ketchikan is next with more than 10,000, followed by Sitka with over 7,000; Wrangell has 3,000; Petersburg, about 2,000; Haines, 1,600; and Metlakatla, Hoonah, and Skagway from 700 to 1,100. Smaller settlements--often Native villages, logging camps, or cannery locations--generally have fewer than 500 people each.

The 215 million Americans who live outside Alaska are the main group of potential tourists, although foreign tourists also visit this part of Alaska. Even the closest source of tourists is a long way off, however. Seattle is about 700 miles from Ketchikan, the closest Alaskan city, and major population concentrations in California, the Midwest, and the East are much farther away.

Recreational access by Alaskans and outside tourists is difficult and is strongly influenced by the available transportation system. Outside highway access is limited. The main direct road link is from Haines to the Alaskan Highway at Haines Junction. A new road--from Skagway to Carcross--is under construction; its opening is planned for 1978. Hyder, in the southeast corner of southeast Alaska, also has a road into British Columbia that connects to the main North American highway network. State ferries travel the Alaska Marine Highway. Cars are carried on the ferries, but capacity is limited--about 50,000 vehicles were carried in the 12 months ending June 1975.[12] A few cars also are carried on railroad cars from Skagway to Whitehorse in Yukon Territory, which is on the highway.

Southeast Alaska is not well suited for continuous road systems. Local road networks are limited, and some small towns have no roads at all (fig. 27). For example, there are about 150 miles of road outside Juneau, one of the more heavily roaded communities, but a driver can only get about 40 miles away from the city before the roads end.[13] Many towns' road systems are even more limited. In a

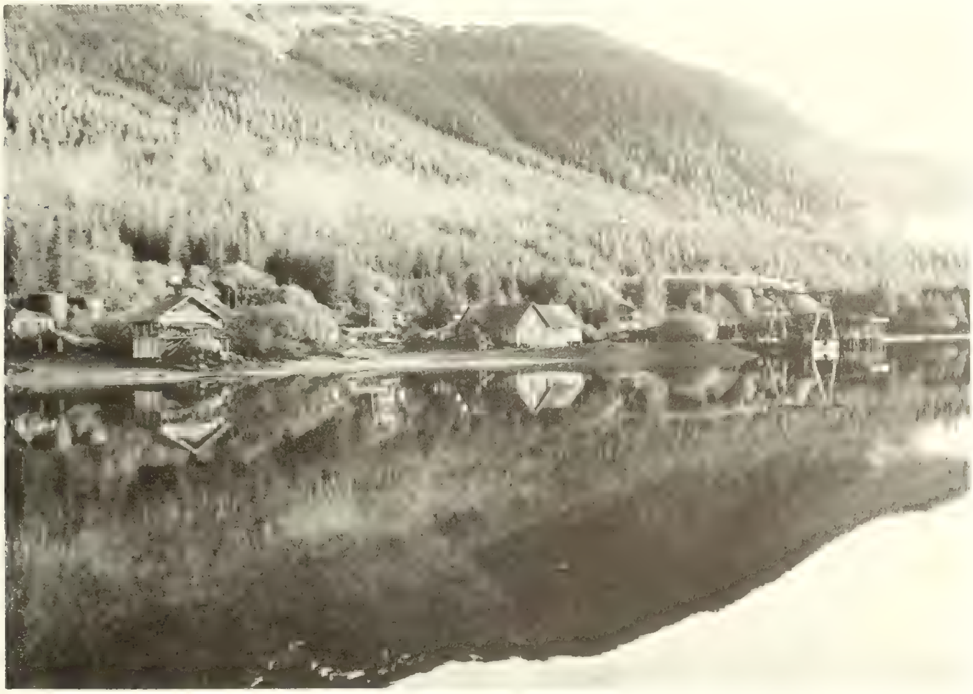

Figure 27.--Some small towns and villages in southeast Alaska have no roads to them but depend on either air or water for transportation.

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[12] Source: State of Alaska Department of Public Works files.

[13] See Homan Associates. Alaska coastal community profiles. 1975. Draft report prepared for Alaska Department of Environmental Conservation, Division of Water Programs, Environmental Analysis Section, Juneau. 954 p.

number of places, however, local road systems are growing greatly, mainly as a result of logging access roads. Prince of Wales Island, the largest of the islands, has an extensive road network--about 800 miles--which opened to the public in 1974.[14] The State ferry system connects with these roads at Hollis, but the service is limited to only a few cars per trip and a reservation is usually required. As of 1975, about 1,000 miles of roads had been constructed on the Tongass National Forest primarily for timber harvest, and about 350 miles of new construction per year are anticipated. Some of this road mileage offers potential access to recreation opportunities of a type commonly found in the lower 48 States--such as berrypicking, fishing, hunting, and camping.

Local motor vehicle ownership does not appear to have suffered in most places, even if roads are scarce (table 3). For example, Juneau had over 7,000 registered vehicles in 1975; Ketchikan, nearly 5,400; Sitka, more than 2,300; and so on. As one result, traffic congestion occurs at rush hours in some towns. As road systems grow, local residents are in a position to make use of them.

Table 3--*Number of motor vehicle registrations by community in southeast Alaska, 1975*[1]

Community	Cars	Pickups	Motorcycles	Snowmobiles[2]	Total
Juneau	4,912	1,693	348	76	7,029
Ketchikan	3,590	1,429	374	2	5,395
Sitka	1,491	682	126	30	2,329
Petersburg	580	431	76	45	1,132
Haines	496	422	80	56	1,054
Skagway	225	221	63	8	517
Wrangell	320	210	24	0	554
Total	11,614	5,088	1,091	217	18,010

[1] Alaska Department of Motor Vehicles.

[2] Many snowmobiles are not registered. The Juneau Trail Plan estimated 450 snowmobiles in Juneau, over 80 percent unregistered.

With the extensive natural waterways in southeast Alaska, boats and ships play a major transportation role in a way that is unmatched elsewhere in the United States. Six State-owned ferries serve 12 southeast Alaska ports as part of the Alaska Marine Highway (fig. 28).

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[14] See the U.S. Forest Service brochure, "Touring in the Prince of Wales Island Road System." Available from the U.S. Forest Service, Alaska Region, Juneau.

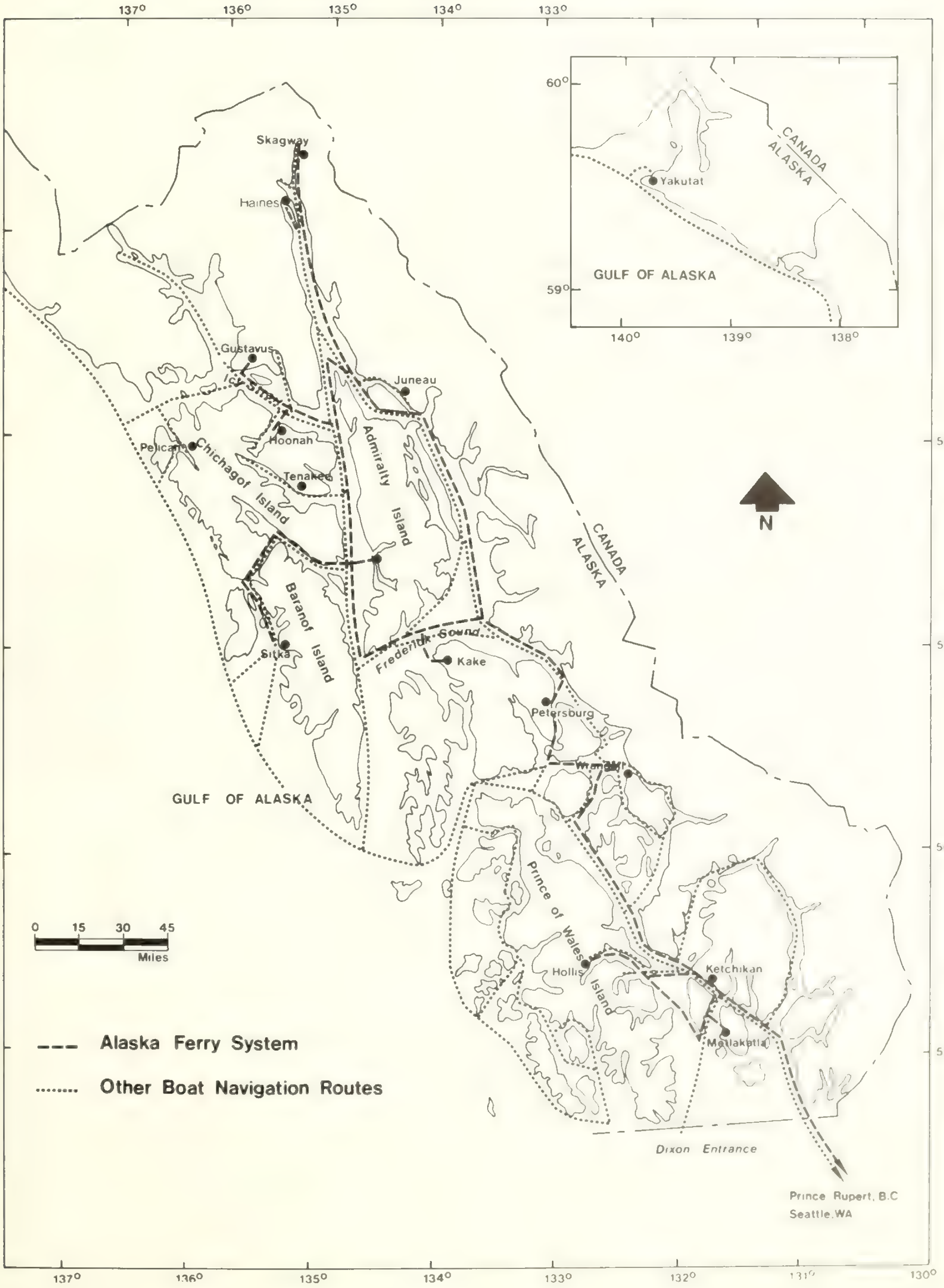

Figure 28.--Location of ferry and cruise ship routes.

Their combined capacity is over 3,000 passengers and 600 vehicles. Running time from Seattle to Skagway, about 1,000 miles, is about 60 hours with short stops in Ketchikan, Wrangell, Petersburg, Juneau, and Haines. One-way fares (1977) between Seattle and Skagway are $93 per passenger and $319 per vehicle (under 19 feet). A two-berth stateroom costs $64. Future plans call for a new stop at Angoon, and requests for service have come from other communities. One ship has been lengthened to accommodate more passengers and vehicles. With the increasing number of stops, opportunities for canoe, hiking, and possibly even driving trips between ports are increased.

Many tour ships sail to southeast Alaska from the lower 48 States and Canada during the summer (fig. 29). Nine companies operate in the area and over 100 tour voyages with more than 400 calls to six ports were made in 1975. Of these, 57 cruised spectacular Tracy Arm and 88 went to Glacier Bay. In 1976, 140 cruises were scheduled, up

Figure 29.--In addition to the State ferries, many tour ships sail to southeast Alaska.

from only 43 in 1973. These ships stop at major ports of call which allows passengers time for sightseeing and souvenir hunting. Most trips take about 8 days with 5 in southeast Alaskan waters.

In 1975, on-board trip costs averaged from $90 to $137 per day, excluding any land-based sightseeing trips or purchase of souvenirs.[15]

The ferry system and tour ships offer passengers a unique opportunity for viewing superlative scenery--including 21-mile-long Wrangell Narrows where the watercourse changes 46 times in a riverlike channel that narrows to a bare 100 yards wide--abundant wildlife in the water, on land, and in the air, and lush vegetation (Hakala n.d.).

Private, smaller boats are common in southeast Alaska; they fill much of the transportation gap left by the scarcity of roads (fig. 30).

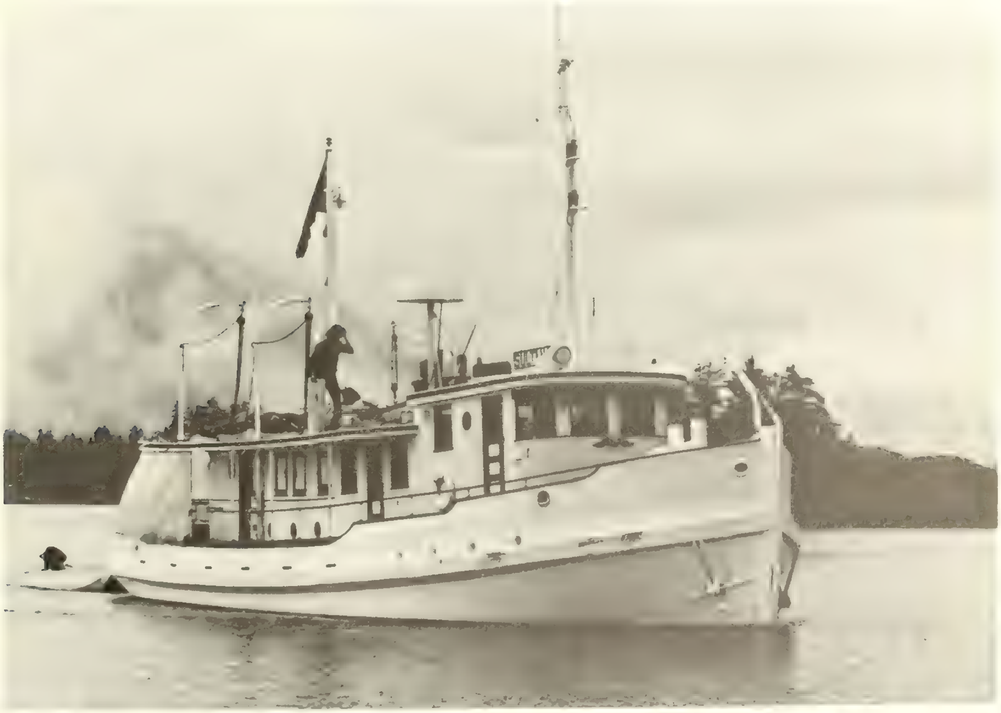

Figure 30.--Private boats are common in southeast Alaska and fill much of the transportation gap left by the scarcity of roads.

The Coast Guard estimates that there are more than 14,000 registered boats in southeast Alaska--almost as many boats as cars. This number does not include the numerous canoes, skiffs, kayaks, and other smaller boats. Over two-thirds of these registered boats are private pleasure boats (not commercial fishing or charter boats). These boats play much the same role in recreational travel as cars do elsewhere, and many of the larger boats are also used for on-board living accommodations in place of the campers or trailers used in roaded recreation areas elsewhere. Some larger private motor and sailboats from the lower 48 States cruise to Alaska, mostly through the inside passage. Distance and dangerous navigational conditions have held this number down, but private cruising is thought to be growing.

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[15] See Eric McDowell. Tourism in Alaska's coastal zone: an economic study. 1975. Draft report prepared by Homan-McDowell Associates for Alaska Department of Environmental Conservation, Division of Water Programs, Environmental Analysis Section. 1975 p.

Charter boats complete the water transportation picture, both fishing boats (the Alaska Division of Tourism lists 17 companies in southeast Alaska offering charter fishing), and "water taxis" providing only transportation (State of Alaska Department of Commerce and Economic Development 1976).

Air travel is the other major means of transportation in southeast Alaska. Figure 31 identifies scheduled airline routes.[16] There are five levels or types of air transportation. Scheduled major airlines connect the main towns with the lower 48 States and the rest of Alaska. Local scheduled airlines connect the larger and smaller towns within southeast Alaska. Next come charter flights (16 charter flight firms are listed for southeast Alaska) which go when and where passengers want to go (within reason!). Floatplanes are popular. They play an important role in southeast Alaska air travel (fig. 32). Most bays and lakes offer potential landing sites, which makes most of the area accessible by floatplane. Finally, many Alaskans are licensed pilots and a number own their own planes. Although figures are not available for southeast Alaska specifically, Federal Aviation Administration records indicate that nearly 10 times as many Alaskans as other U.S. citizens are licensed pilots (on a per capita basis).

RECREATION PROGRAMS, AREAS, AND DEVELOPMENTS

Several Federal and State agencies have programs related to recreation in southeast Alaska. But recreation developments, facilities, and special areas are not common--in fact, part of the appeal of southeast Alaska to many people is the sparse development. Some developments, however, play a key role in providing a range of opportunities for recreation and a basis for recreational use of much of the undeveloped, wild country. Table 4 shows the jurisdiction of lands with recreational objectives in southeast Alaska and the classification of these areas. Recreation developments described below are listed in table 5. The location of major developments is shown in figure 33.

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[16] Resource Planning Team (1975) identifies the location of all airports and floatplane bases in southeast Alaska.

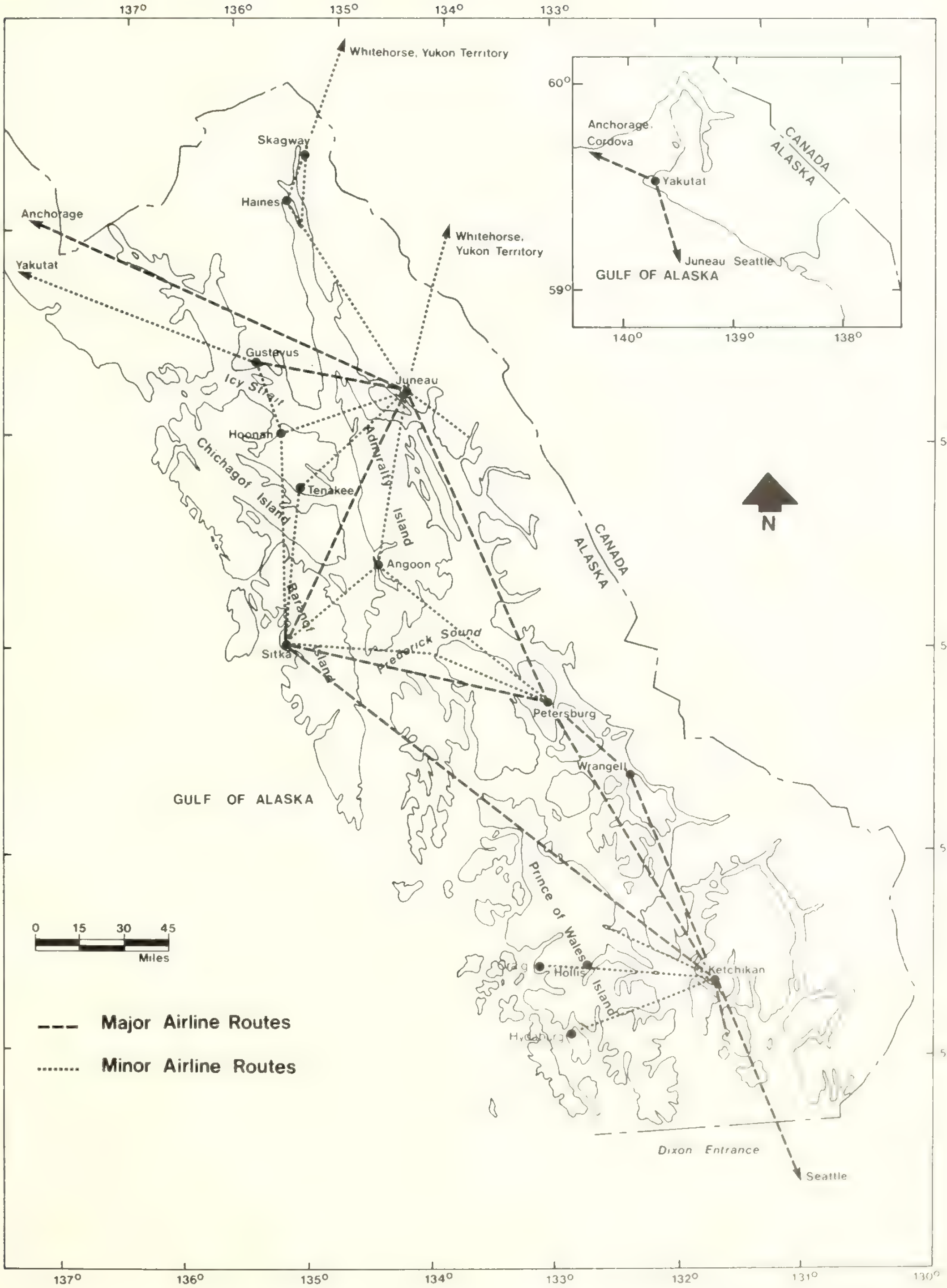

Figure 31.--Location of landing facilities and scheduled airline routes in southeast Alaska.

Figure 32.--Floatplanes are popular. They play an important role in southeast Alaska air travel.

Table 4--*Southeast Alaska areas with management objectives that include recreation*

Type of classification	Administration					
	Federal[1]	State[2]	Local	Quasi-public	Private	Total[3]
	Acres					
Basic classification:						
Land	16,678,814	406	506	21	264	16,680,011
Wetland	1,554,672	--	2	--	--	1,554,674
Freshwater	787,564	6	114	1	--	787,685
Total[3]	19,021,050	412	622	22	264	19,022,370
Bureau of Outdoor Recreation classification:[3]						
Class I (high density recreation areas)	23	16	141	7	--	187
Class II (general outdoor recreation areas)	5,701	334	48	10	250	6,343
Class III (natural environment areas)	16,305,389	--	395	1	12	16,305,797
Class IV (unique natural areas)	2,542,990	--	--	--	--	2,542,990
Class V (primitive areas)	166,600	--	4	2	--	166,606
Class VI (historic and cultural sites)	193	62	--	--	--	255

Source: State of Alaska Department of Natural Resources (1970b).

[1] Bureau of Land Management areas are not included.

[2] The 6,045-acre Chilkat State Park, established after this compilation, is not included.

[3] Because inventory forms were not always filled out in detail, totals for the two sets of classifications do not always agree.

Table 5--*Inventory of recreation areas and facilities, southeast Alaska,* [illegible][1]

Facility	Private		Local		State		Federal		Total	
	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity
Play, sport areas	0	0	39	3,095	2	40	1	15	42	3,150
Ice skating areas	0	0	3	175	0	0	0	0	3	175
Picnic units	12	48	71	400	47	188	163	821	293	1,457
Camp units	30	120	40	180	73	304	321	1,592	464	2,196
Trails (miles)	2	37	4	150	42	800	[2]14	144	[4]62	1,131
Downhill ski areas	1	25	0	0	0	0	[3]3	450	4	475
Sledding areas and ski jumps	0	0	1	25	0	0	0	0	1	25
Swimming beaches and pools	1	50	3	390	3	250	3	150	10	840
Boat launching and mooring spaces	20	80	4	1,600	3	236	5	50	32	1,966
Nature centers	0	0	1	20	0	0	0	0	1	20
Other	0	0	5	268	6	228	61	1,519	72	2,015
Total capacity		360		6,303		2,046		4,741		13,450

[1] From preliminary draft of Alaska Outdoor Recreation Plan Summary.

[2] Other sources list 377 miles of National Forest trail (U.S. Forest Service files).

[3] The ski areas are locally operated or privately operated facilities on Federal land under special use permits. Eaglecrest at Juneau has opened since this tabulation and the Douglas Snow Bowl has closed.

[4] Other sources list 370 (State plan revision) to 430 miles (State trail plan) of trail.

Private and Commercial Developments

There are 13 lodges scattered across the Alaskan Panhandle (State of Alaska Department of Commerce and Economic Development 1976). They vary from highly developed resorts, and lodges, some with swimming pools, to rustic cabins. Almost all the lodges feature fishing and sightseeing, and many also provide hunting. Some lodges are located on public land, under special use permits.

Small, downhill ski areas serve local residents in Ketchikan and Petersburg. Eaglecrest, a larger area with chairlifts, has just opened in Juneau.

Charter boat and air services were discussed in the section on the "Setting" under "Population and Transportation."

Local Government Areas

Local government recreation programs have emphasized day use activities, traditional city parks, ballfields, and indoor facilities.[17] A moderate number of local outdoor recreation areas are

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[17] "Recreation on National Forest Lands in Alaska." Preliminary report submitted to the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, Portland, Oregon, by the Agricultural Experiment Station, University of Alaska, Fairbanks. Available from Recreation Research, 4507 University Way N.E., Seattle, Washington 98105.

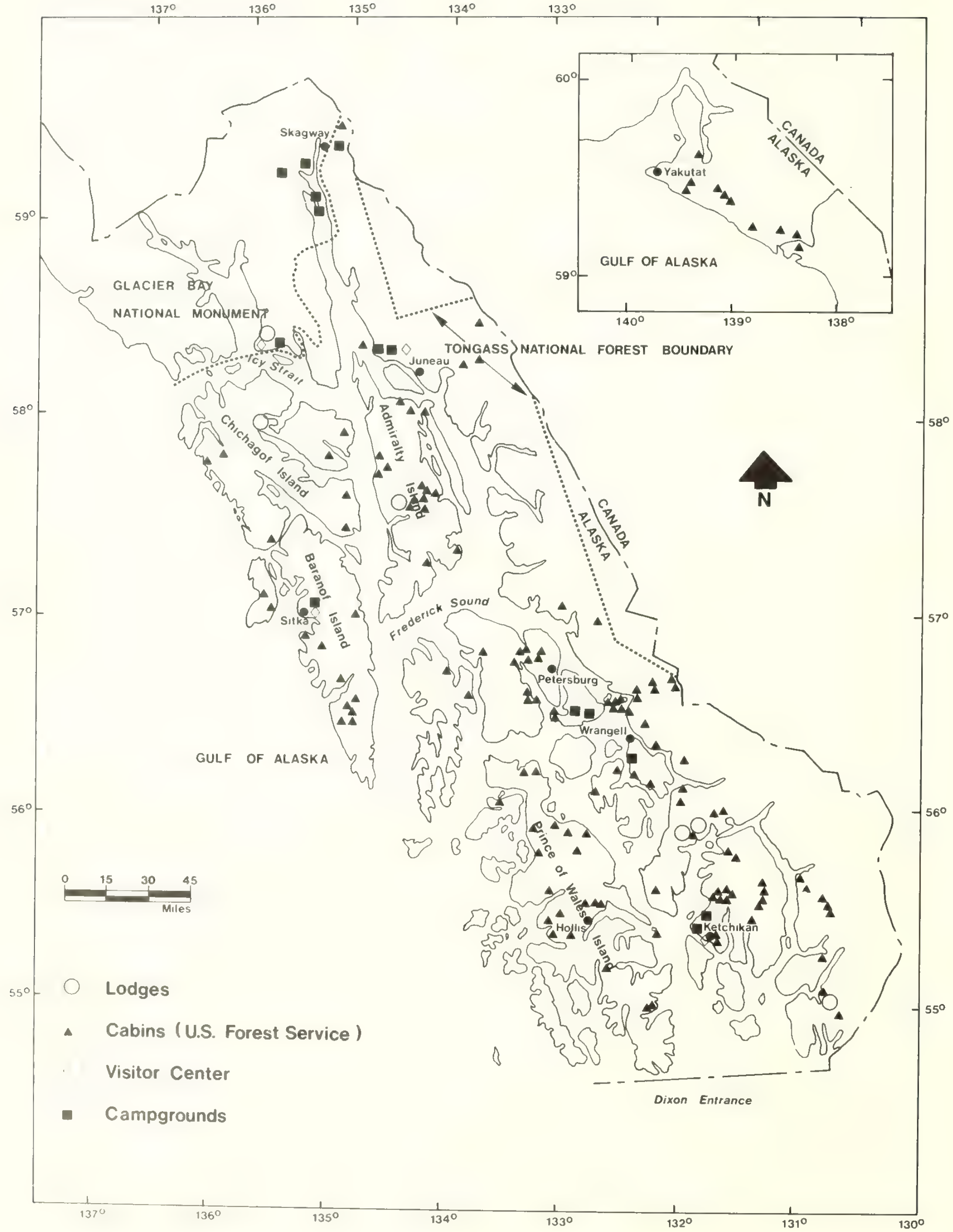

Figure 33.--Location of major recreation developments in southeast Alaska.

developed, particularly play areas, picnic areas, swimming areas, and most of the boat mooring and launching areas. Several areas, including Juneau, have local trail systems. The developments tend to be concentrated in and around the larger communities. Most of the smaller villages have little recreational development.

State Areas

The State Park system's objectives include providing parks and recreation areas of regional and statewide significance and promoting preservation of historical areas and objects of significance to Alaskan citizens. State development is rather limited in southeast Alaska because most of the land is under Federal ownership. Ownership could shift as the State selects land for community expansion and recreation. There are over 40 miles of State trail, most in the Skagway-Chilkoot Pass and Juneau areas (State of Alaska Department of Natural Resources n.d.). Historic sites are located at Old Sitka and Baranov Castle Hill at Sitka, and Totem Bight at Ketchikan. Fort William H. Seward, at Haines, is on the National Register of Historic Sites but is privately owned. Seven road waysides, generally developed for camping and picnicking are located near Haines, Sitka, Wrangell, and Ketchikan. Several cabins used at times by the Department of Fish and Game for research in the Stikine area are used by the public at other times.

Federal Areas

National Park Service

The National Park Service is charged with providing recreation of national significance and, at the same time, preserving significant natural and historical areas in their natural condition. National Park units in southeast Alaska include huge, spectacular Glacier Bay National Monument--almost 3 million acres of fiords, glaciers, and fascinating areas only recently emerged from under glaciers--57-acre Sitka National Historical Park, featuring earlier Russian and Tlingit Indian settlements, and the Klondike Gold Rush National Historic Park in the Skagway area. Facilities at Glacier Bay include interpretive facilities (U.S. Department of the Interior, National Park Service 1976), a concessionaire-operated lodge, a campground, a marine gas and oil dock, about 11 miles of trail, and charter boat and flight service. Park Service naturalists go aboard all cruise ships at Glacier Bay and explain the natural features of the area to visitors while the ships are in Glacier Bay. No roads connect Glacier Bay to outside points, except to nearby Gustavus. Much of the monument (2.2 million acres) has been proposed as a wilderness. The Klondike Gold Rush National Historical Park, established in 1976 by P.L. 94-323, consists of units in Skagway, the White Pass Trail, the Chilkoot Trail, and in Seattle, Washington.

An interpretive center in Skagway is planned. Several historic buildings are also being restored for display. The combined size for all the units of the new Klondike Gold Rush Park is about 14,000 acres. At Sitka National Historical Monument, an interpretive center and 5 miles of trail enable visitors to see 14 Tlingit totems, four house posts, and the Sitka battleground, including the site of the Tlingit fort.

Fish and Wildlife Service

The U.S. Fish and Wildlife Service has three relatively small National Wildlife Refuges (total area less than 3,000 acres), all on islands in the Pacific west of the main, large islands of the Alexander Archipelago: Forrester Island, Hazy Islands, and St. Lazaria. These refuges are closed to hunting and fishing. All three refuges are also units of the National Wilderness Preservation System.

Forest Service

The U.S. Forest Service manages the largest number of acres in southeast Alaska. Most of the capacity in campgrounds and picnic areas of southeast Alaska is on the Tongass National Forest. Thus far most of the emphasis in recreation developments has been to retain the natural quality of the areas involved. This is reflected in the primitive level of development of facilities provided; of the 230 sites listed in the Forest Service Recreation Information Management (RIM) System data, 82 percent (188) are level 2 developments,[18] and most of the remainder are level 3 (table 6). Ten campgrounds and 26 picnic grounds are shown on the Tongass National Forest map (available for $0.50 from local Forest Service offices in Alaska). These facilities are all located in road-accessible areas near the major communities.

In direct contrast, Forest Service public recreation cabins--unique to the National Forest System--are away from roads. There are 151 of these cabins. As many as 40 cabins are within 20 minutes flying time of some towns. Many were built and are maintained by the Alaska Territorial Sportsmen or local groups with Forest Service guidance. The cabins, available by reservation for general public use for a small overnight fee, are located on lakes, rivers, and ocean shore and near hot springs. They are almost always isolated from other cabins. A few are double cabins designed for two parties. They have bunks, a stove, and usually a boat. Access is usually by floatplane, boat, or both; some cabins in the Yakutat are reached

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[18] Definitions of campground development levels are given in table 6.

Table 6--*Development levels of Forest Service facilities in southeast Alaska*

Development level	Number of sites	Percent
1. Primitive, minimum site modification. No motorized access provided or permitted. Spacing informal and extended (wide spacing) to minimize contacts with others.	1	0
2. Secondary primitive, little site modification. Motorized access provided or permitted. Spacing informal and extended to minimize contacts with others.	188	82
3. Intermediate, site modification moderate. Primary access may be over high standard, well-traveled roads. About 3 family units per acre.	39	17
4. Secondary modern, site heavily modified. Primary access over paved road. About 3 to 5 family units per acre.	2	1
5. Modern, high degree of site modification. Access usually by high-speed highways. 5 or more family units per acre.	0	0
Total	230	100

Source: Recreation Information Management (RIM) System. USDA Forest Service, Alaska Region, Juneau, Alaska. More complete definitions are given in the RIM handbook.

by wheeled aircraft. There are an additional 76 private recreation cabins on sites leased from the Forest Service and 30 hunter cabins available to the public.

Trails on the National Forest are fairly limited and are located mainly around communities (fig. 34). Figures reported for trail mileage vary greatly, probably because of different definitions related to condition, whether or not the trail is maintained, etc.; but the Forest Service reports 377 miles of trails. Few trails have been built for a number of years; but in 1976, Youth Conservation Corps members constructed three new trails in the Three Lakes area near Petersburg.

There are three ski areas on special use permits located on National Forest lands. Uncertain snow conditions and limited demand by small resident populations limit development in most other locations.

There is a portable visitor center at Ward Lake near Ketchikan and a permanent center at the Mendenhall Glacier near Juneau. Forest Service naturalists ride the State ferries in the summer (fig. 35) and help passengers understand and enjoy the panhandle environment

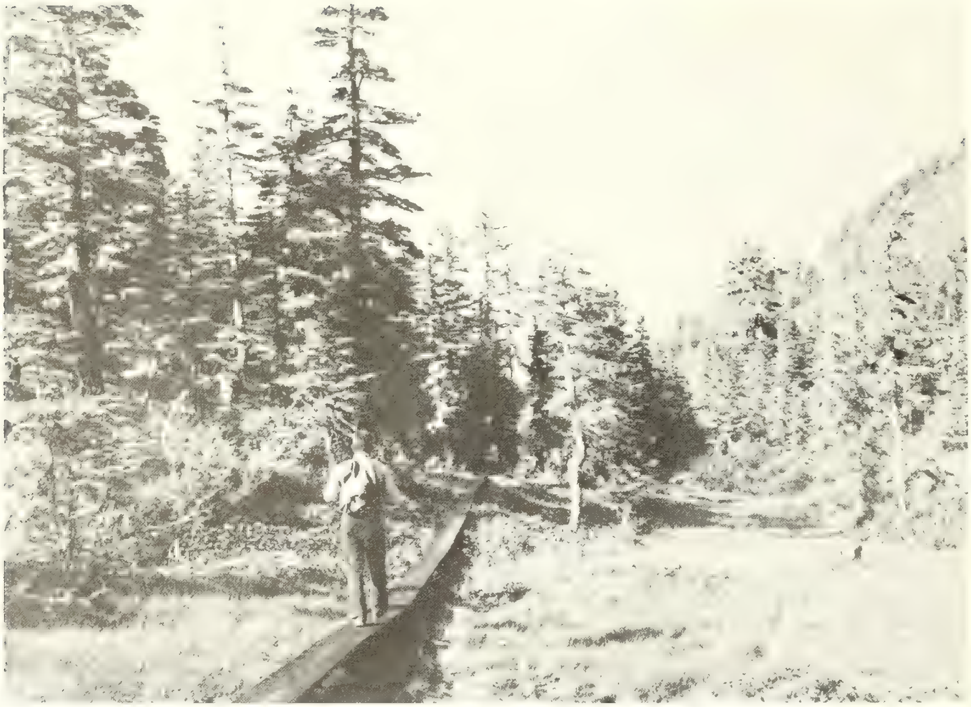

Figure 34.--Trails on the National Forest are limited. Few trails have been built in recent years.

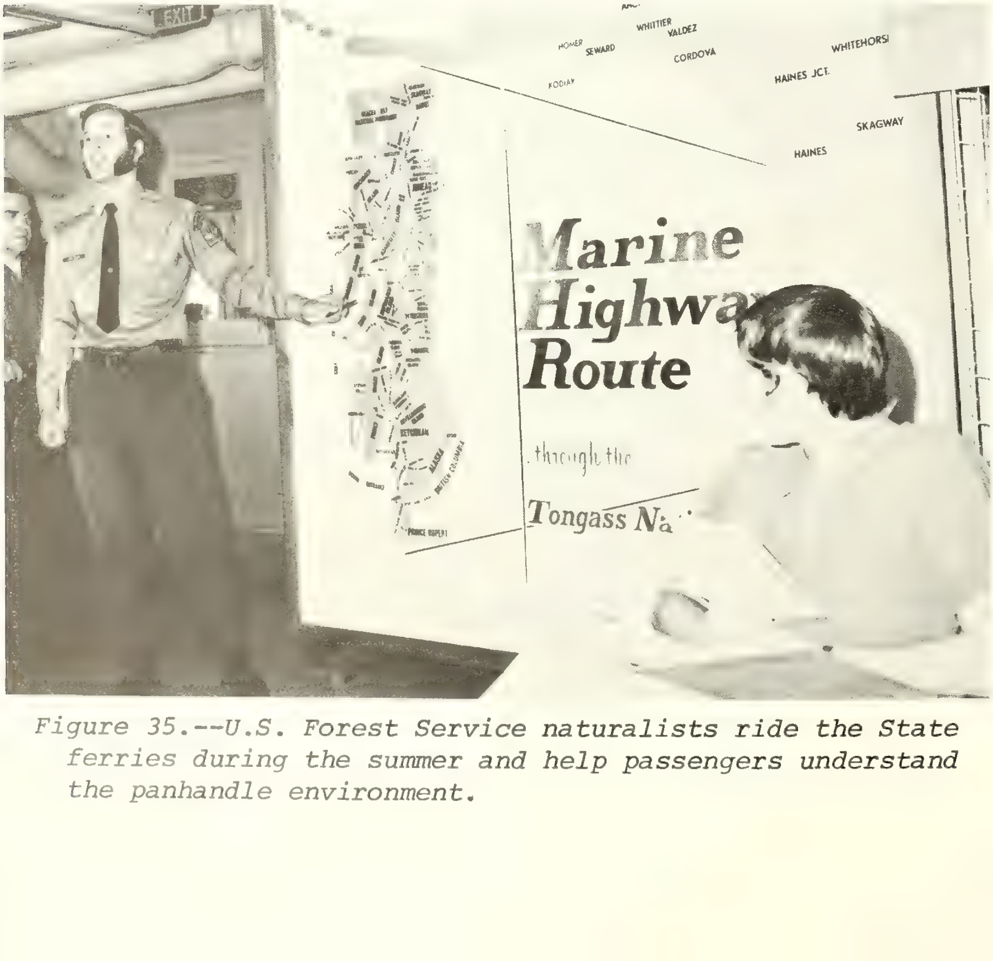

Figure 35.--U.S. Forest Service naturalists ride the State ferries during the summer and help passengers understand the panhandle environment.

(Hakala (n.d.). This program operates under a cooperative agreement between the Forest Service and the Alaska Division of Marine Transportation. There are also 13 minor interpretive sites. Three trails are set up for self-guided tours.

The National Forest has several types of special areas of esthetic and recreational significance (USDA Forest Service 1977a). There are two large, superb scenic areas--Tracy Arm-Ford's Terror (283,000 acres) and Walker Cove-Rudyerd Bay (94,000 acres). Both are located on the mainland, Tracy Arm south of Juneau and Walker Cove northeast of Ketchikan. Both areas are also within Wilderness Study Areas.

Geological attractions are found at the new Eddystone Rock Area (1 acre) near Ketchikan; archeological and cultural features at New Kasaan Totem Park (11 acres) near Ketchikan; the Fish Creek Recreation Area (8,710 acres) near Juneau; the Seymour Eagle Management Area (fig. 17), with a high concentration of eagle nests and typical range of eagle food sources, adjacent to Admiralty Island (10,778 acres) (Robards and Taylor n.d.); the Mendenhall Glacier Recreation Area at Juneau (5,900 acres); Admiralty Lakes Recreation Area on Admiralty Island (110,000 acres); and Ward Lake Recreation Area (4,800 acres) on Revillagigedo Island near Ketchikan.

Research Natural Areas include Limestone Inlet and Cape Fanshaw (9,102 and 600 acres) on the mainland, Old Tom Creek (4,234 acres) on Prince of Wales, Pack Creek (5,779 acres) on Admiralty Island (it features a bear observatory), and Dog Island (802 acres) south of Ketchikan. Additional Research Natural Areas are planned. They are established primarily for scientific purposes and have only limited recreation potential.

Six Wilderness Study Areas covering 1.9 million acres and representing about 13 percent of the nearly 15 million acres of roadless and undeveloped lands (fig. 36) are under study on the Tongass National Forest--Tracy Arm, Granite Fiords, King Salmon Capes, Petersburg Creek, Russell Fiord, and Khaz Bay. Tracy Arm includes the Tracy Arm-Ford's Terror Scenic Area but also much more; it covers over 780,000 awe-inspiring acres on the mainland south of Juneau (fig. 37). Granite Fiords also includes a scenic area--Walker Cove-Rudyerd Bay--and a large surrounding area, totaling 590,000 acres, extending from saltwater to icefields on the Canadian border northeast of Ketchikan. Russell Fiord near Yakutat includes 227,000 acres of magnificient deep water fiords. King Salmon Capes, 119,000 acres on a group of islands west of Prince of Wales Island, represents the Pacific coast islands. Petersburg Creek (24,000 acres) is an outstanding example of typical timber and muskeg and high country in combination with the estuarine-stream-lake complex of spawning and rearing habitat for salmon, steelhead, cutthroat trout, and Dolly Varden. Khaz Bay (40,000 acres) on Chichagof Island includes scenic mountains and islands along open coast and protected waters.

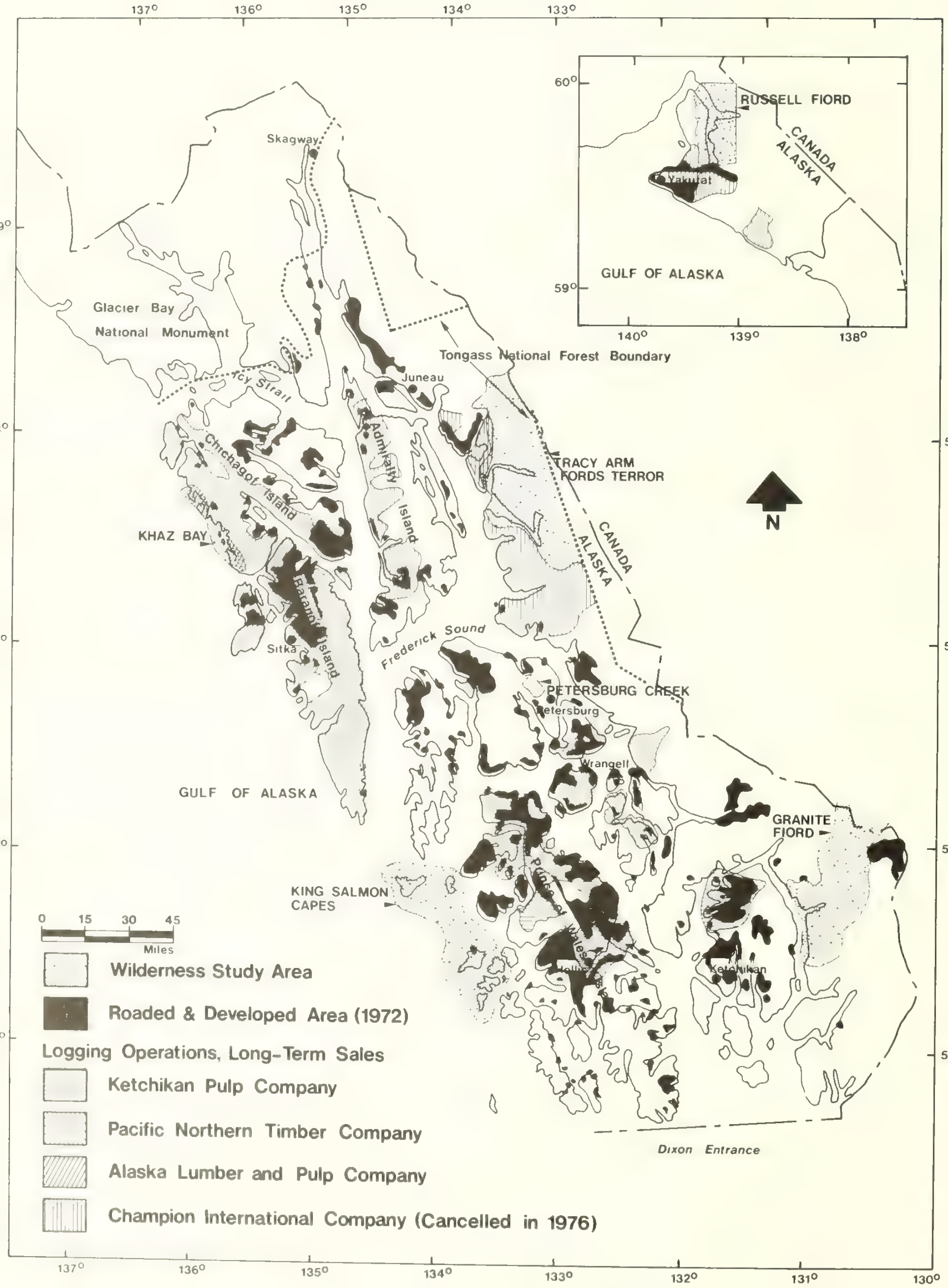

Figure 36.--National Forest land status.

Figure 37.--Tracy Arm Wilderness Study Area covers over 780,000 awe-inspiring acres south of Juneau.

SUMMARY OF SCENIC AND RECREATION RESOURCES IN SOUTHEAST ALASKA

What southeast Alaska has to offer in the way of scenic and recreational attractions is summed up in the advertising literature. McDowell (see footnote 15) estimates nearly 75 percent of advertising space is spent on promoting natural features; most of the remainder is spent on historical and cultural attractions. The primitive and rugged quality of southeast Alaska contrasts sharply with other vacation spots.

Summarizing this richness is difficult because of the immensity of the area, unavailability of information, and the scattered and variable nature of existing recreation developments. The Joint Federal State Land Use Planning Commission recently attempted this task (Stenmark and Schoder 1974). Although the Commission recognized the inadequacy of much of the data they compiled, and cautioned users about it, it does represent one of the few efforts to assess recreation potential in this area. Interested readers will find details on the procedures used and the results of the survey in the Stenmark and Shoder's publication.

RECREATIONAL USE

There is tremendous potential for diverse forms of recreation in southeast Alaska, but the remote location and small resident population makes it difficult to tell how much use actually takes place. The limited data existing are generally poor, are often outdated, or are based on questionable sources; indeed, limited data on recreational use was cited as a major problem in the 1962 Outdoor Recreation Resources Review Commission (ORRRC) report. Little progress has been made since. Few formal studies have been conducted; data-gathering for administrative purposes has been minimal and unreliable; and the methods used have varied among agencies. The data base from which projected use figures are derived is outdated, and no reliable data are available from which to build a new data base (State of Alaska Office of the Governor 1975). The Governor's office also stressed that "the lack of accurate information on tourism impact and characteristics within the State is a concern. . .although some Division of Tourism information is built on actual field work. . .much more is estimated." Definitional problems regarding tourism (see footnote 15) and different reporting periods (fiscal vs. calendar years) further confuse the issue. U.S. Forest Service estimates of visitor use of dispersed and developed areas are obtained through their RIM System; but because of the diverse and often unobservable use over such large areas, most of these figures are only rough, often unreliable, estimates at best. And, although relatively good information is available about some uses (Forest Service cabins, for example), literally nothing exists about others. Use data for the National Park Service areas, especially Glacier Bay, are among the better recreation use figures.

Two additional major difficulties in using the available data on recreation use and users confront persons interested in understanding use patterns: (1) in many cases, data on southeast Alaska are difficult to separate from the rest of Alaska; (2) resident use and tourist recreation use are quite often reported together, making it difficult therefore to ascertain the relative impacts of these two distinct user groups.

Despite all these difficulties, some broad, general outlines of the nature and extent of recreation use in southeast Alaska can be drawn in this section, although the results must be used with caution.

TOURIST INFLOWS[19]

Data showing the number of visitors entering all of Alaska by various modes of transportation for several years since 1964 are shown in table 7. With the exception of marine travel (ferries and cruise ships), almost all of which is in the southeast, it is difficult to ascertain the proportion of visitors to southeast Alaska. More than 40-55 percent of all visitors to Alaska are estimated to spend at least part of their time in the southeast portion of the State (Hinkson 1964, State of Alaska Department of Natural Resources 1971). Other statistics indicate that about 90 percent of these visitors are from the continental United States and almost all the remainder from Canada, Japan, and Europe.

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[19] McDowell's "Tourism in Alaska's Coastal Zone: An Economic Study" (see footnote 15) is the most recent reference on this topic.

Table 7--*Estimated number of tourists entering Alaska, by mode of transportation*[1]

Year	Travel mode				Total
	Cruise ship[2]	Ferry	Airline	Highway	
1964	11,000	11,650	13,250	23,300	59,200
1967	13,200	18,950	20,600	33,950	86,700
1970	27,000	20,000	38,000	44,000	129,000
1973	36,400	28,800	84,100	66,000	215,300
1974	46,200 (38,856)	30,200 (46,076)	94,200	66,000	236,600
	- - - - - - - - - - - - Percent - - - - - - - - - - - -				
Average annual increase, 1964-73	13	11	22	15	15
Increase from 1973 to 1974	27	5	10	0	10

[1] Figures before 1968 are from Cresap et al. (1968). The 1973-74 figures are estimates by the Alaska Division of Tourism. Numbers in parentheses are estimates quoted in Eric McDowell, Tourism in Alaska's Coastal Zone: An Economic Study (1975). Draft report prepared by Homan-McDowell Associates for Alaska Department of Environmental Conservation, Division of Water Programs, Environmental Analysis Section. 175 p.

[2] Figures for cruise ships visiting Glacier Bay National Monument as reported by the National Park Service are 18,481 people in 1973; 41,531 in 1974; 42,479 in 1975; and an estimated 54,000 for 1976.

At present, it is impossible to determine the number of people entering southeast Alaska from the lower 48 States or Canada by private plane or boat. But observers feel that, although the numbers are small compared with total visitors, they are increasing.

Of interest to public recreation area managers and private recreation facility operators is the high degree of seasonality in tourist inflows (table 8). This is a common phenomenon in other areas of the country but seems particularly pronounced in Alaska. Summers are short; and winter sports are largely undeveloped, although they are growing.

Table 8--*Travel to Alaska (entire State), by month, 1973*

Month	Number of passengers (including tourists)				Total	Percent of total[1]
	Cruise ship	Ferry	Airline	Highway		
January	--	6,731	24,074	2,280	33,085	5
February	--	6,640	16,640	2,273	25,553	4
March	--	8,441	20,886	2,800	32,127	5
April	195	9,192	21,870	4,956	36,213	6
May	1,930	14,239	26,772	6,542	49,483	8
June	7,114	26,953	42,012	13,657	89,736	14
July	11,160	40,247	44,842	24,105	120,354	18
August	9,924	38,281	43,974	21,237	113,416	17
September	5,779	18,615	26,360	11,287	62,041	9
October	454	9,209	21,886	3,700	35,249	5
November	--	5,803	18,952	2,663	27,418	4
December	--	7,250	22,850	2,132	32,232	5
Total	36,556	191,601	331,118	97,632	656,917	100

[1] 66 percent of visitors arrived during the summer season, May through September.

In 1973, an attempt was made by individual passenger carriers and the Alaska Division of Tourism to determine the purpose for visiting Alaska (Dindinger 1973). The findings are shown in table 9. These data illustrate the tremendous importance of recreation and scenic resources for visitors to Alaska--75 percent of all travelers indicated the purpose of their trip included pleasure. Of these, 67 percent traveled solely for pleasure. An even higher proportion (90 percent) of southeast Alaska visitors traveling by either ferry or cruise ship gave this reason.

Travelers to southeast Alaska by ferries and cruise ships have opportunities to leave their ships in most ports of call, which allows them to visit local attractions. These stops are also important to local economies. Cruise ship passengers typically spend only a few hours ashore and often tour the area as part of organized groups. The number of people spending time ashore from these ships is not available. Ferry passengers on the other hand

Table 9--*Reasons given by travelers for visiting Alaska, by mode of entry in 1972*[1]

Mode and reason	Number	Percent
Airline:		
Tourist and pleasure	24,684	29
Visit friends and relatives	45,230	54
Business and pleasure	14,217	17
Total	84,131	100
Highway:		
Tourist and pleasure	60,523	92
Visit friends and relatives	4,128	6
Business and pleasure	1,397	2
Total	66,048	100
Marine highway:		
Tourist and pleasure	22,827	79
Visit friends and relatives	4,570	16
Business and pleasure	1,350	5
Total	28,747	100
Cruise ship:		
Tourist and pleasure	35,609	98
Visit friends and relatives	563	1.5
Business and pleasure	201	.5
Total	36,373	100
Tourists--all modes of transportation		215,299

Source: Dindinger (1973).

[1] About 55 percent of all travelers were included in the survey.

are left on their own and many leave the ships--most for a few hours, but some until the next ship going their way arrives. Table 10 shows the number of passengers and vehicles landing in several southeast Alaska ports. The proportion of total passengers (and vehicles) accounted for by residents and tourists is impossible to calculate. But the high proportion of offloadings during the summer season indicates tourist impacts and use of nearby recreation areas and facilities may be considerable. One source indicated that a high proportion (55-60 percent) of summer ferry users during 1974 were nonresidents (see footnote 15); other data from the same report indicate that for June of 1975, 57 percent of Seattle boarders and 44 percent of Prince Rupert boarders sailed straight to Haines and Skagway, and 54 percent of Haines boarders and 37 percent of Skagway boarders sailed straight to Prince Rupert or Seattle. The conclusion is that, with the exception of Juneau and Ketchikan, the other ports

Table 10--*Number of vehicles and passengers arriving in southeast Alaska ports on the Marine Highway system, 1974*

Port	Number of vehicles[1]	Number of passengers[1]
Ketchikan	5,566 (58)	24,739 (62)
Wrangell	1,911 (59)	9,190 (55)
Petersburg	2,116 (56)	11,360 (88)
Sitka	1,766 (51)	6,574 (56)
Juneau	7,328 (59)	33,371 (66)
Haines	9,381 (65)	28,079 (70)
Skagway	2,322 (61)	18,795 (77)

Source: State of Alaska, Department of Public Works, Division of Marine Transportation.

[1] Numbers in parentheses indicate the percentage of vehicles and passengers disembarking during the summer season, May through September.

of call receive few visitors coming ashore from the ferries.

Just who the southeast Alaska visitor is has not been well documented. Several earlier studies describe visitors to all of Alaska, but specific figures for the southeast region were not developed (Hinkson 1964; State of Alaska Department of Natural Resources 1964 (fig. 38).

The economic importance of this tourist inflow to southeast Alaska is not well understood. The 1975 study by McDowell (see footnote 15) indicates that economic impact ranges from slight to heavy with larger communities receiving the most impact and the majority of communities receiving little or no impact. But the data base is questionable. McDowell sums up the problem in stating, "The message here is that no data exist which are suitable for measuring the economic importance of tourism as an economic force." To be sure, tourism represents big investments on the part of vacationers, but the proportion ending up in southeast Alaska rather than elsewhere in Alaska or the United States is unknown.

McDowell also indicates that for an important tourist industry to develop requires three conditions--attractions, transportation, and accommodations. There is no question the region has the attractions. But the nature of the transportation system and accommodations available have important implications for tourism. Larger communities such as Juneau, Ketchikan, Skagway, and Haines have the ability to deal with tourists, but most others do not. And with most visitors traveling and living on cruise ships and ferries, the potential for economic benefits and associated impacts on local facilities in southeast Alaskan communities may be limited.

Figure 38.--Just who uses the recreational opportunities available in southeast Alaska is not well known. Little research has been conducted to determine what residents and tourists do to enjoy the area and how recreation affects local communities.

RECREATIONAL USE BY MAJOR ACTIVITIES

During fiscal year 1973, nearly 2 million visitor-days were spent in various public recreation areas and undeveloped lands and waters in southeast Alaska (table 11). What do all these recreationists do to enjoy the area's tremendous outdoor recreation and scenic resources? Based on the limited information available, the following general description presents what is known concerning current resident and nonresident recreation participation in southeast Alaska. Available data on participation rates for major activities of southeast Alaskans, as well as visitors to the area, are discussed for important categories of dispersed and developed activities. Unfortunately, information about the experiences these users were seeking (the real product of recreation management) is

Table 11--*Recreational use of Federal, State, and local government areas in southeast Alaska, fiscal year 1973*

Level of government	Visitor-days[1]	Percent of total
Federal areas	1,657,500	91
State areas	85,500	5
Local areas	72,800	4
Total	1,815,800	100

Source: State of Alaska, Department of Natural Resources (1976).

[1] Rounded to nearest hundred. A visitor day is defined as the presence of a person for recreation purposes for 12 hours.

nonexistent; the number of "visits," "visitor days," etc., only indicate the relative importance of activities, based on how many participate. Tables 12 and 13 present the most comprehensive data available concerning outdoor recreation activities in southeast Alaska. The results of a survey of 1967 recreation participation rates of regional residents are shown in table 12. Although these data are based on only a small sample and are not representative of all the region's residents, they do, when combined with more recent information, including the 1975 use figures from management areas on the Tongass National Forest (fig. 39 and table 13), help paint a picture of the activities favored in this area. Data concerning use of State and National Parks are shown in tables 14 and 15. From these data, the following generalizations can be made about dispersed and developed recreation activities.

Dispersed Forms of Recreation

Most of Alaska, southeast included, is known for its abundant opportunities to "get away from it all." Many residents and nonresidents alike take advantage of this fact and head for the wilds to boat, hunt, fish, camp, hike, beachcomb, pick berries, and to do the many other things possible in this vast region. Because of the highly dispersed nature of this type of recreation (indeed, a major part of the appeal), information on the amount of dispersed recreation occurring is difficult to obtain (fig. 40). There are some data, however, which are indirect measures of the amount of dispersed use which is summarized in part in the preceding tables and in the following discussion. But one must keep in mind the "invisible" character of such recreation when interpreting the findings. Because it is dispersed, much of it is inconspicuous and easily overlooked. The available data probably underestimate the nature and extent of many dispersed recreation activities.

Table 12--*Participation of southeast Alaska residents in selected outdoor recreation activities, 1967*[1]

Activity	Percent of population participating (12 years and older)	Average annual participation	
		Days per person	Days per participant
Trail-related activities:	88	80.9	91.9
Walking for pleasure	77	43.2	56.1
Nature study	50	21.5	43.0
Bicycling	23	7.4	32.2
Hiking	43	3.5	8.1
Snowmobiling	3-	.1	3.3
Motorcycling	10	2.3	23.0
Snowshoeing	3-	.2	6.7
Canoeing	7	.6	8.6
Horseback riding	7	.2	2.9
Dog sledding	1-	.03	3.0
Cross-country skiing	3-	.3	10.0
Mountain climbing with gear	5	.4	8.0
Picnicking	88	16.1	18.3
Driving for pleasure	82	35.5	43.3
Sightseeing	81	35.6	44.0
Fishing:	67	13.4	20.0
Freshwater	40	3.9	9.8
Saltwater	56	9.4	16.8
Ice	2-	.1	5.0
Motorboating	59	11.4	19.3
Swimming:	48	8.8	18.3
Lake and stream	21	2.0	9.5
Pool	18	2.6	14.4
Ocean	34	4.2	12.4
Hunting:	36	4.6	12.8
Big game	30	2.8	9.3
Small game	10	.9	9.0
Waterfowl	12	.9	7.5
Outdoor sports and games	36	7.9	21.9
Camping	35	3.2	9.1
Ice skating	25-	1.5	6.0
Snow play	17-	1.4	8.2
Flying for pleasure	14	1.5	10.7
Alpine skiing	7-	.7	10.0

Source: State of Alaska Department of Natural Resources (1967; 1970b, p. V-17 to V-50).

[1] Based on a sample of 377 people from the boroughs of Juneau, Sitka, and Ketchikan.

Table 13--*Summary of Tongass National Forest recreation use for three management areas, 1975*

(In thousands of visitor-days[1])

Activity	Management areas			Total
	Chatham	Stikine	Ketchikan	
Boating:				
Ships, yachts, ferries	171.0	72.0	115.5	358.5
Smaller powerboats	30.0	65.9	39.2	135.1
Canoeing	2.9	.5	1.2	4.6
Sailing	2.8	.5	.4	3.7
Rowing, drifting, rafting	2.3	1.3	1.9	5.5
Total	209.0	140.2	158.2	507.4
Fishing:				
Freshwater	18.8	6.6	18.4	43.8
Saltwater	53.0	80.7	52.7	186.4
Total	71.8	87.3	71.1	230.2
Hunting:				
Big game	31.0	6.4	9.6	47.0
Small game	1.0	.6	.4	2.0
Upland birds	1.1	.5	.3	1.9
Water fowl	6.9	43.8	5.1	55.8
Total	40.0	51.3	15.4	106.7
Recreation travel (mechanized):				
Autos	45.0	6.3	10.6	61.9
Motorcycles	4.5	.6	1.1	6.2
Ice or snow craft	15.6	4.9	3.2	23.7
Total	65.1	11.8	14.9	91.8
Picnicking	25.6	4.3	13.4	43.3
Hiking and walking	14.1	4.5	20.6	39.2
Camping:				
General	33.1	0	10.3	43.4
Auto	7.8	.3	.9	9.0
Trailer	5.0	.2	.5	5.7
Tent	6.4	11.4	14.2	32.0
Total	52.3	11.9	25.9	90.1
Visits (exhibits, talks, etc.):				
Interpretive exhibits	19.5	0	1.0	20.5
Programs and talks	8.3	0	0	8.3
Unguided tours (walking)	31.0	0	1.4	32.4
Interpretive signs	9.0	0	.4	9.4
Audio programs	4.0	0	0	4.0
General information	1.0	0	.6	1.6
Total	72.8	0	3.4	76.2
Winter sports:				
Ice skating	3.0	.2	1.0	4.2
Sledding-tobogganing	1.5	0	.1	1.6
Skiing	24.1	.4	1.9	26.4
Snowplay	16.6	.6	2.4	19.6
Total	45.2	1.2	5.4	51.8
Viewing:				
Scenery	5.2	.8	.9	6.9
Unique, unusual environments	5.0	0	.5	5.5
Spectator sports	2.0	0	0	2.0
Total	12.2	.8	1.4	14.4
Recreation residence use	8.9	2.3	.5	11.7
Gathering forest products	5.6	1.6	4.0	11.2
Water sports:				
Swimming-bathing	2.1	.8	2.0	4.9
Diving	.8	.3	1.5	2.6
Waterskiing, etc.	.4	.3	.6	1.3
Total	3.3	1.4	4.1	8.8
Organized camp use	8.0	0	.7	8.7
Nature study	3.2	.5	4.3	8.0
Games and team sports	4.1	0	1.6	5.7
Bicycling	3.2	.3	.3	3.8
Horseback riding	1.8	0	0	1.8
Resort use	.6	0	0	.6
All activities	646.8	319.4	345.2	1,311.4

Source: U.S. Forest Service Recreation Information Management (RIM) Center, Recreation Use Information for Alaska. Washington, D.C.

[1] Recreation use of National Forests is measured in visitor-days. One visitor-day is defined as 12 visitor hours which may be any combination of numbers of people and time spent (e.g., 1 person for 12 hours or 12 people for 1 hour).

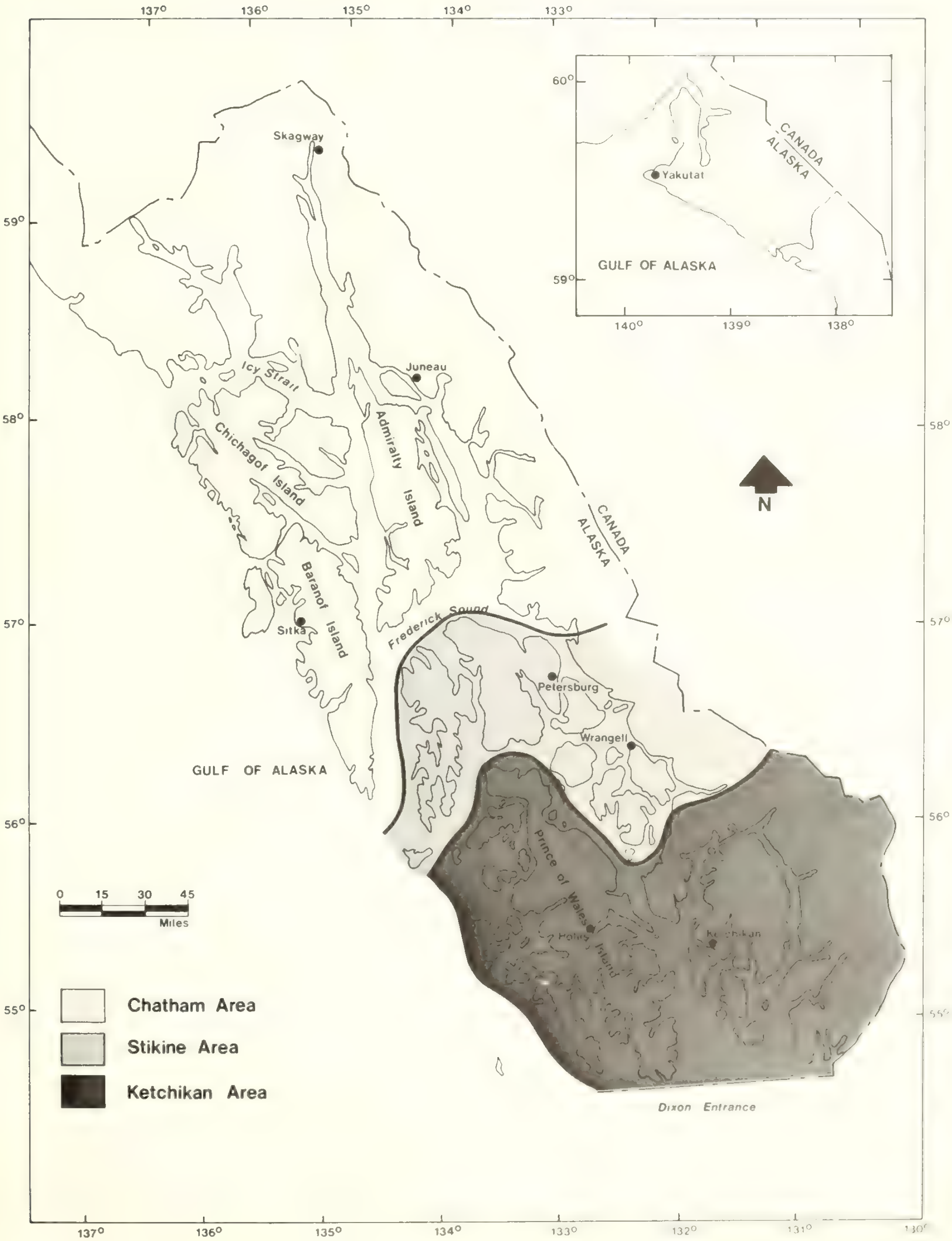

Figure 39.--Management areas on the Tongass National Forest.

Table 14--*Summary of visits to the Alaska State Park System by sites in southeast Alaska, July 1, 1973 to June 30, 1974*[1]

Location of site by borough	Resident	Nonresident	Total
Ketchikan borough:			
Refuge Cove Picnic Wayside	8,016	4,343	12,359
Totem Bight Historic Site	11,123	24,819	35,942
Knudson Cove Boat Launch[2]	1,872	472	2,344
Total	21,011	29,634	50,645
Wrangell area:			
Pat's Creek Campground	180	814	994
City and borough of Sitka:			
Baranov Castle Historic Site	755	186	941
Halibut Point Picnic Wayside	7,146	751	7,897
Old Sitka Historic Site	2,287	6,737	9,024
Total	10,188	7,674	17,862
City and borough of Juneau:			
Sheep Creek Trail	509	40	549
Mount Roberts Trail	2,207	1,281	3,488
Perseverance Mountain, Juneau, and Granite Creek Trails	6,472	1,413	7,885
Total	9,188	2,734	11,922
Haines borough:			
Chilkoot Lake Campground and day use area	2,107	13,378	15,485
Portage Cove Campground	754	3,456	4,210
Mosquito Lake Campground	1,227	971	2,198
Total	4,088	17,805	21,893
Skagway:			
Liarsville Campground	366	661	1,027
Chilkoot Trail[3]	205	204	409
Total	571	865	1,436
Total southeastern region	45,226	59,526	104,752

Source: State of Alaska Department of Natural Resources, Division of State Parks.

[1] Visits are defined as the entry of an individual for recreation purposes.

[2] Now under Division of Water and Harbors.

[3] Other data in National Park Service files show heavier use for this period: 296 visits by residents, 810 by nonresidents, for a total of 1,106.

Table 15--*Summary of recreation use data for National Park areas in southeast Alaska during 1976*

Glacier Bay National Monument:	
Total visits	84,945
Overnight stays, total:	12,628
Lodge	9,983
Campgrounds	1,068
Backcountry	1,577
Special use data number of visits:	
Tour boat (in Park tours)	6,546
Tour aircraft	458
Fishing charters	1,056
Cruise ships	46,488
Sitka National Historical Park:	
Total visits	81,624

Source: Superintendents, Glacier Bay National Monument and Sitka National Historical Park.

Figure 40.--Because of the highly dispersed nature of recreation in southeast Alaska, information on the amount of recreation occurring is difficult to obtain (photo, courtesy of Chuck Horner).

The locations of outdoor recreation participation in dispersed activities on the Tongass National Forest are shown in table 16.

Table 16--*Use of dispersed recreation areas on the Tongass National Forest during 1975*

Type of area	Visitor-days[1]	Percent
Ocean	703,300	61
General undeveloped	178,100	16
Roads	99,200	9
Lakes, ponds	58,200	5
Trails	52,700	5
Rivers, streams	40,700	4
Reservoirs	1,000	0
Total	1,133,200	100

Source: U.S. Forest Service Recreation Information Management (RIM) Center, Washington, D.C.

[1] Recreation use of National Forests is measured in visitor-days. One visitor-day is defined as 12 visitor hours which may be any combination of numbers of people and time spent (e.g., 1 person for 12 hours or 12 people for 1 hour).

The importance of marine and freshwater environments is obvious. More than 70 percent of such activities are water-oriented, mostly on saltwater. "General undeveloped" areas also account for a significant portion of the total dispersed use.

Hunting and Fishing

With the diverse and abundant fish and wildlife populations in this region of Alaska, it would be surprising if hunting and fishing were not major recreation activities. The data in table 12 indicate that more than one-third of the residents hunt and more than two-thirds fish. On the Tongass National Forest, fishing is the second most popular recreation activity in terms of visitor-days; hunting is third (table 13).

Table 17 shows license sales for 1974. Of the more than 25,000 fishermen, 39 percent were nonresidents. Only 8 percent of licensed hunters were nonresidents.

At Glacier Bay in 1976, 1,056 people used the fishing charter service, up from 772 in 1975 and from 321 in 1974.[20]

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[20] Source: Superintendent, Glacier Bay National Monument.

Table 17--*Sport fish and game license sales in southeast Alaska, 1975*[1]

Licenses sold	Residents[2] (percent of total)	Nonresidents (percent of total)	Total
Fishing	15,717 (61)	9,915[3] (39)	25,632
Hunting	10,243 (92)	895 (8)	11,138
Trapping	1,651 (100)	3 (0)	1,654

Source: State of Alaska Department of Fish and Game.

[1] Residents under 16 years of age are not required to have licenses for either hunting or fishing. Nonresidents under 16 years of age need a license for hunting, but none for fishing. Residents of Alaska for 30 years and persons over 60 years old do not need a license.

[2] A person must live in Alaska 12 months to qualify for a resident hunting or fishing license.

[3] 6,295 (60 percent) of these were 10-day visitor licenses.

Tables 18 and 19 show the harvest from fishing and from hunting. State of Alaska Department of Fish and Game[21] estimates indicate

Table 18--*Estimated catch and time investment for sports fishermen in southeast Alaska, 1973*[1]

Species	Number of fish caught
Dolly Varden	46,800
Cutthroat trout	25,000
Coho salmon	22,200
Pink salmon	20,000
Chinook salmon	9,400
Halibut	7,000
Sockeye salmon	5,000
Chum salmon	4,100
Rainbow trout	3,000
Steelhead	2,000
Brook	1,000
Arctic grayling	200
Total	145,700
Angler-days	156,880
Fish caught per angler-day	0.9

[1] Data provided by State of Alaska Department of Fish and Game, Division of Sports Fisheries.

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[21] Sports Fishery Division. Another source (McDowell 1975, footnote 15) estimates the number of man-days of fishing in southeast Alaska to be over 300,000 and the catch to exceed 460,000 fish in 1973. National Forest data for the Tongass National Forest in 1975 show just over 200,000 man-days.

Table 19--*Reported big game harvest in southeast Alaska, 1973-74 season*

Animal	Number harvested	Limit per person	Percent nonresident[2]
Deer	[1]5,000-7,817	3-4	--
Moose	367	1	--
Mountain goat	327	2	[3]13-73
Black bear	66	2	42
Brown bear	132	(4)	35
Wolf	94	0	--
Total	5,986-8,803		

Source: Compiled from State of Alaska Department of Fish and Game harvest records.

[1] Two methods are used by the Alaska Department of Fish and Game for estimating deer kills-harvest tickets and interviews. The range from 5,000 (harvest tickets) to 7,817 (interviews) deer harvested results from these two procedures.

[2] -- means "not reported."

[3] The number indicates the variation in proportions between game management units reporting these data.

[4] 1 every 4 years.

that, for 1973, sport fishermen spent over 150,000 days in catching more than 145,000 fish. Major species caught were Dolly Varden, cutthroat trout, the five salmon species, and halibut. During 1974, residents of the three largest cities (Juneau, Sitka, and Ketchikan) were estimated to have spent nearly 200,000 hours fishing on 45,000 ocean fishing trips (USDA Forest Service 1977a).

Little information exists regarding the success of big game hunters. But in the 1973-74 season, about 6,000 to 9,000 big game animals were taken in southeast Alaska (table 19), the majority of which were deer. Ninety-four wolves were harvested; nearly three-fourths of these were shot, the rest trapped. The majority of wolves are thought to have been shot while the hunter was after other species or was involved in nonhunting activities.

A recent study indicates that hunting, as might be expected, is largely a male-oriented sport, although the proportion of women who hunt is on the rise (see footnote 17)--mostly younger women. A significantly higher proportion of women were found to be anglers.

Difficult access in and around southeast Alaska is part of the unique appeal of this area, and offers special difficulties (or attractions, depending on one's perspective) for the hunter and fisherman. Both sports are almost exclusively water oriented except near the local towns. Using charter services--boats and planes--to get to favored hunting grounds is a way of life for most nonresident sportsmen and for many resident sportsmen seeking locations at some distance from settlements. Many residents own pleasure boats, which are often used for hunting and fishing. Others use canoes along streams or at many of the lakes in the area.

For the nonresident, guide services are usually necessary and are required by law for hunting some species unless one is accompanied by a resident. Many of the lodges feature accommodations, transportation, and guide services. Recreation cabins are frequently used as base camps for hunting and fishing.

Boating

The more than 14,000 registered boats estimated to be in southeast Alaska indicate the importance of boating to local populations. Although boating in itself is often a pleasurable activity, in this area its major importance is transportation for other recreation activities (fig. 41). In southeast Alaska, the boat also often substitutes for the camper vehicle of the lower 48 States.

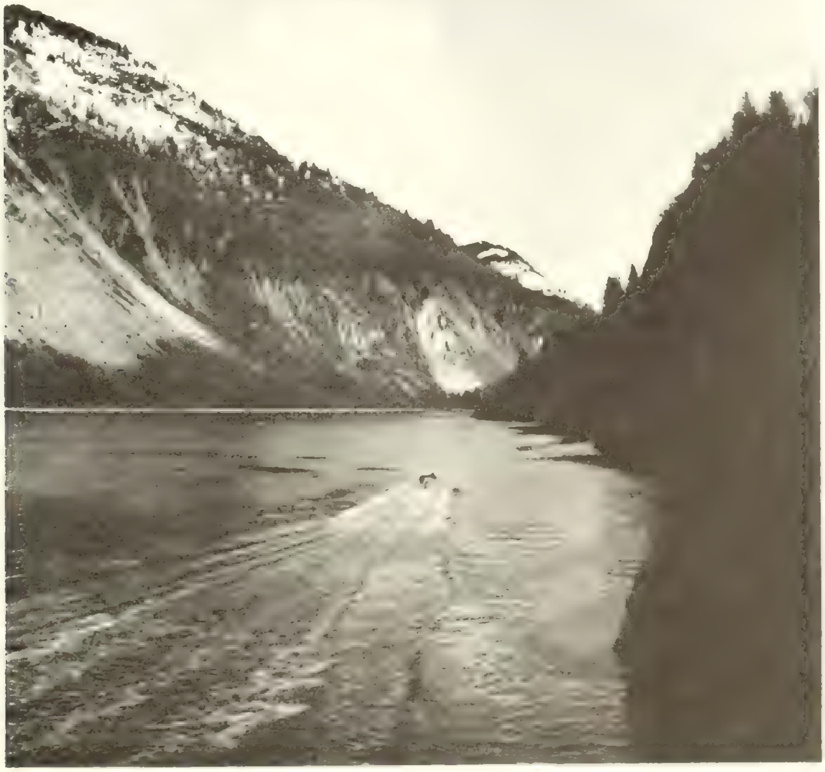

Figure 41.--Boating is a pleasurable activity and boats are the primary way to reach many recreation opportunities in southeast Alaska (Plateau Glacier in Glacier Bay National Monument).

Information on recreational boating activities is sparse. The United States Coast Guard registration figures include only motorized boats over 16 feet in length. The many skiffs, canoes, kayaks, etc., are not included, yet these are important recreation equipment for many people. Types of boats vary from skiffs to huge cruisers, and many families own several kinds. The number of sailboats is also increasing.

More than 65 percent of southeast Alaskans participate in motorboating or canoeing (table 12). Within the National Forest, boating (including yachts, ferries, cruise ships) is by far the most important activity; more than twice the number of visitor-days are reported for boating than for any other activity (table 13). Park officials report that more than 1,000 private boaters reportedly entered Glacier Bay during 1975.

Not included in these figures are nonresident boaters venturing up the coast or along the Inside Passage from the lower 48 States. Although estimates of this type of use are not available, observers indicate the use is growing. Ketchikan residents estimated seeing about 50 nonresident boats in port per week from the lower 48 States during the summer (see footnote 17). Several Seattle-based organizations offer the would-be adventurer into southeast Alaskan waters advice on where to go and how to stay afloat.

Both motorized and nonmotorized forms of recreational boating are growing. The abundant marine, lake, and stream settings offer spectacular and isolated locations for whatever style of water travel one is seeking. An increasing number of resident and nonresident recreationists transport their rafts, canoes, or kayaks to prize locations. Two recreational trails include tramways where open boats of up to 20 feet can be loaded for portages between bodies of water. These facilities were built during the Civilian Conservation Corps days and are in a state of disrepair, offering potential hazards to the unwary. Other developments such as moorages, docks, and landings have been built in many areas (often for commercial purposes many years ago) and are used by recreational boaters.[22]

Sightseeing

Viewing the many attractions of southeast Alaska is a major activity (fig. 42). The explosive growth in visits to tour ships is based mainly on the appeal of sightseeing. Data related to the nature of this activity and how much takes place by boats and ships, planes, autos, or other modes of transportation are, however, sparse.

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[22] An inventory of marine facilities in southeast Alaska has been compiled by the Alaska Division of Parks in Juneau.

Figure 42.--Viewing the many attractions of southeast Alaska is a major activity (photo, courtesy of Chuck Horner).

More than four-fifths of southeast Alaska residents reported that they engaged in sightseeing in 1967 (table 12). How they do it is unknown; but it undoubtedly takes many forms, often a part of other recreation activities such as the extensive boating described in the previous section. More than 20,000 visitor-days of nature study and viewing scenery and unique environments were reported for the Tongass National Forest in 1975 (table 13).

One would think that the importance of driving for pleasure would be limited by the few roads in southeast Alaska, but more than 80 percent of southeast Alaska's residents report this activity (table 12). Whether they do this exclusively around their local communities or use the Alaska State ferry system is not known. Mechanized recreation travel on the Tongass National Forest ranks fourth in the number of visitor-days of use (table 13).

National Park Service figures for 1976 show that nearly 85,000 visitors came to Glacier Bay National Monument, one of the most spectacular locations in southeast Alaska (table 15). Many of these visitors saw the area from the deck of comfortable ships and viewed a rugged and undeveloped landscape, complete with a rich natural and cultural history and diverse wildlife populations.

Certainly for the visitor to southeast Alaska, sightseeing is a major attraction--whether on foot, on the water from the deck of a State ferry or cruise ship, on the narrow gage railway from Skagway to Whitehorse, Yukon Territory, in the air from a chartered plane, or even from a commercial airliner at 35,000 feet.

The importance of sightseeing is highlighted by the number of buslines, charter planes, boat companies, and even guides offering their services for sightseeing purposes in most communities.

Hiking

Although the total number of miles of formal trails in southeast Alaska is small, hiking appears to be an important recreation activity for many people. With the absence of roads and trails in most locations, foot travel is necessary to reach many land-based attractions, whether on one of the islands or on the mainland. After flying or boating to the chosen area for an outing, many people spend part of their time hiking either for a particular experience or for other activities such as fishing, hunting, nature study, beachcombing, and camping. Many favored locations can also be reached by the trails leading from some of the communities in the area. Other recreationists may prefer to venture cross country across wild lands (fig. 43), although this type of travel is difficult in forested

Figure 43.--A wealth of undisturbed natural and cultural resources are available for the visitor who chooses to sightsee by striking out across primitive areas.

areas near the water because of dense brush and concern for brown bear encounters.

Southeast Alaska affords an abundance of such opportunities, and it is not surprising that nearly 80 percent of southeast Alaskans report walking for pleasure as an activity (table 12). In addition, almost half the residents indicate some time spent hiking. The distinction between the two forms is not clear, but the importance of foot travel is important. On the Tongass National Forest, nearly 40,000 visitor days were spent hiking (table 13). Whether on the trails or striking out cross country, the hiker has unlimited opportunities for exercise, solitude, and appreciation of outstanding natural settings.

The total amount of hiking at Glacier Bay National Monument is not known, but it certainly would include the 1,577 back-country users during 1976 (table 15). More than 12,000 people reportedly used State Park trails in 1974; about 25 percent of these people were nonresidents (table 14). In the newest National Park, Klondike Gold Rush Historical Park, approximately 1,500 hikers crossed the Chilkoot Pass in 1976. A survey of the hikers is being conducted (1977) by the National Park Service.

In a 1974 survey of hikers around Juneau, users felt that "the trails need to be better physically maintained, the tread needs to be kept free of running water, brush needs to be cut, both for comfort and as a safety factor in spotting bears, and some clearing for views could enhance the hikers' experience." This same study also gathered data related to all types of trail use which allows some comparison with earlier studies. These data indicate that (at least for Juneau residents) hiking is nearly twice as popular as reported in the earlier study of southeast Alaskans (72 vs. 43 percent) (see footnote 17). Trails now receive more winter use than they did a few years ago, mainly for cross-country skiing.

Public Cabin Use

Rapid growth in use of U.S. Forest Service recreation cabins since 1970 is shown in table 20 (fig. 44). Popularity of cabins on lakes and canoe routes has greatly increased. In 1975, nearly 32,000 people used the cabins on the Tongass National Forest. Only a few of the cabins approach maximum capacity, however (fig. 45). Most cabins are used at less than 20 percent of capacity. Cabins that offer the easiest access and best opportunities for enjoying scenery, hiking, fishing, and hunting, are the most frequently used. Many of the lesser used cabins are older buildings and are hard to get to. Several once-popular cabins no longer receive much use, reportedly because of logging in the area. For example, Luck Lake cabin usage has declined from 100 visitor-days in 1970 to no use in 1975. Lack of information about the attractions available at some

Table 20--*Forest Service recreation cabin use by management area*

Year	Chatham		Stikine		Ketchikan		Total[1]	
	No. of parties	No. of people	No. of parties	No. of people	No. of parties	No. of people	No. of parties	No. of people
1970	[2]390	[2]1,576	NA	NA	NA	NA	390	1,576
1971	[3]168	[3]988	NA	NA	710	2,019	878	3,007
1972	[4]652	[4]2,255	297	1,058	632	2,401	1,581	5,714
1973	[3]244	[3]1,129	456	1,627	748	2,621	1,448	5,377
1974	[2]762	[4]3,776	473	1,764	667	2,322	1,902	7,862
1975	[2]767	[4]3,784	534	2,028	751	2,631	2,052	8,443
Total	2,983	13,508	1,760	6,477	3,508	11,994	8,251	31,979

Source: U.S. Forest Service Recreation Information Management (RIM) data, Alaska region, Juneau.

NA = Not available.

[1] For areas reporting data.

[2] Reported by Sitka and Juneau; Yakutat report missing.

[3] Sitka only; others missing.

[4] Reported by all three districts (Sitka, Juneau, and Yakutat).

Figure 44.--Southeast Alaska offers 151 public recreation cabins managed by the U.S. Forest Service.

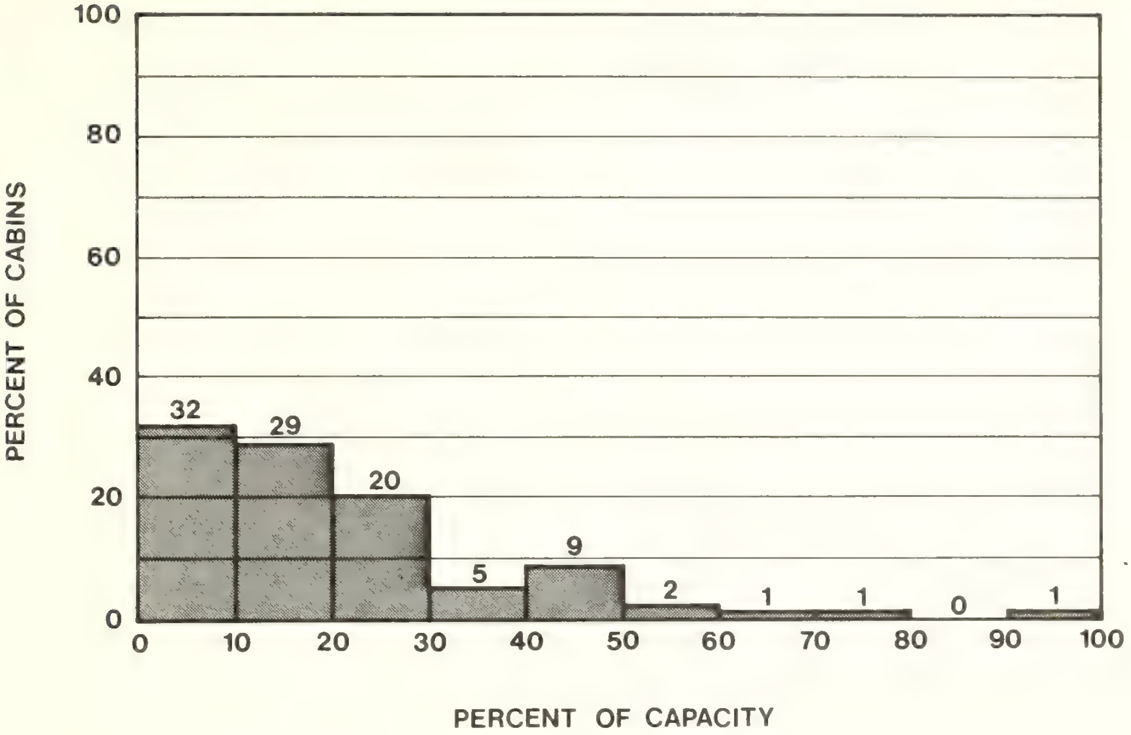

Figure 45.--Use based on 151 cabins. The theoretical seasonal capacity is the time that the cabin is considered usable in a normal season (calendar days) X people at one time X 2. This estimate varies between cabins.

cabins may also explain their low use. Much of the use occurs during the summer months for fishing, although a high proportion of cabins near prime hunting areas are used in hunting season. This use is sensitive to changes in length of hunting seasons and limits as well as to fluctuations in game populations. Other cabins are used throughout the year.

Table 21 identifies the residence of persons registering for use of cabins during the 1975 season. Most (91 percent) were from southeast Alaska, but some residents of other States and Canada ventured here. Observers feel that this number is increasing annually and that Alaska residents often register for out-of-State guests who use the cabins. These data would, therefore, underestimate the total amount of nonresident use. A cooperative study between the U.S. Forest Service and the University of Alaska is underway on cabin users in one area of the Tongass National Forest.

Dispersed Camping

More than a third of all southeast Alaskans report that they camp (table 12). National Forest data indicate that, for 1975, more than 90,000 visitor days were spent camping; 84 percent of this was in general camping and tent camping--other than with autos or

Table 21--*Residence of groups using Forest Service cabins in southeast Alaska for 1975, by management area*[1]

Registrant's residence[2]	Chatham		Stikine		Ketchikan		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Alaska:								
Southeast	269	90	497	93	683	90	1,449	91
Other	9	3	0	0	4	0	13	1
Total	278	93	497	93	687	90	1,462	92
Outside Alaska:								
United States	[3]20	7	[4]37	7	65	9	122	8
Canada	0	0	0	0	3	0	3	0
Total	20	7	37	7	68	9	125	8
Total registrants	298	100	534	100	755	100	1,587	100

Source: Compilation of U.S. Forest Service cabin reservation data.

[1] These data are based on all areas but the Juneau and Yakutat districts of the Chatham area which had incomplete data.

[2] Based on residence of person registering. This probably understates use by persons living outside southeast Alaska because persons living in southeast Alaska may register for friends or relatives from other areas.

[3] U.S. residents: 8 Pacific Northwest; 9 Southwest; 2 East; 1 Northeast.

[4] U.S. residents: 15 Pacific Northwest; 11 Southwest; rest scattered throughout country.

[5] U.S. residents: 30 from Pacific Northwest; rest scattered throughout country.

trailers (table 13). Although these data do not allow us to determine the amount of dispersed camping away from facilities (cabins, campgrounds, etc.), the opportunities are abundant (fig. 46); and

Figure 46.--Camping at undeveloped sites is a popular activity in southeast Alaska (photo, courtesy of Chuck Horner).

it would be surprising if this activity was not substantial. Most overnight boating and floatplane trips would necessarily require camping, so the number of participants is undoubtedly quite large. At Glacier Bay, over 1,500 visitors stayed overnight in the area during 1976 (table 15).

As a response to the apparent popularity of dispersed camping, a pamphlet on beach camping has been prepared by the U.S. Forest Service which outlines the precautions necessary for camping in remote areas (Constantine 1976).

Private Cabins

Under special permit, the Forest Service has leased 76 private cabin sites in southeast Alaska and reports nearly 12,000 visitor days for them in 1975 (table 13). The extent of use of other private recreation cabins not located on National Forest lands is not known. This is one of the few National Forests in the Nation still offering this opportunity, although few sites are being leased now. Many other regions of the country have been forced to terminate this use because of increasing recreational pressures.

Dispersed Winter Sports

Dispersed winter sports in southeast Alaska include cross-country and alpine skiing, snowshoeing, sledding, tobogganing, ice fishing, some dog mushing, ice skating, snow playing, and snowmobiling (fig. 47). Dispersed winter recreation activities are sometimes limited by snow conditions in some areas, unsuitable rough terrain for some activities, dense vegetation, or lack of appropriate formal routes and facilities (trails and shelters) for the snowmobiler and cross-country skiers; but despite these limitations, winter recreation use has grown rapidly in recent years. Generally, the best conditions are in the northern part of the panhandle.

More than 60 percent of southeast Alaska residents report that they participate in some type of winter recreation (table 12); U.S. Forest Service figures show more than 50,000 visitor-days spent in winter sports (table 13). The large amount of winter activities occurring is not surprising because the winter season is long (up to 7 months); but the proportion of those activities taking place in developed vs. dispersed sorts of locations cannot be determined. Some user groups have organized and are reported to have developed shelters and trails in local areas, which is an expression of the popularity of these sports.

Dispersed Road-Oriented Activities

Although the road system in southeast Alaska is not extensive,

Figure 47.--Generally, the best winter sports areas are in the northern part of the panhandle.

road-oriented dispersed recreation plays an important role for many users. The limited roads surrounding the communities provide opportunities for berrypicking, hunting and fishing, camping, and often for access to more remote locations beyond the road's end.

More than 80 percent of southeast Alaska residents report they drive for pleasure (table 12). Nearly 70,000 visitor-days of road travel in autos or motorcycles were reported on the National Forest in 1975 (table 13), although the nature and amount of dispersed road recreation in southeast Alaska have not been well documented.

In addition to the major roads outside the communities, access to timber sale roads through both logged over and natural areas is possible in several areas; use of these locations is reportedly increasing. In other States, dispersed recreation use of roaded areas is increasing rapidly (Hendee et al. 1976); it is not surprising that the same thing would occur in southeast Alaska where the opportunity exists.

On Prince of Wales Island, an extensive road network exists as a byproduct of timber harvest activities and many local residents and some nonresidents recreate along these roads. Local Forest Service managers have prepared a brochure identifying recreational attractions along the road system. The amount of use in this area is not known.

Beachcombing

For the ardent beachcomber, southeast Alaska is a dream come true. The nearly 30,000 miles of tidal shoreline speak clearly enough for the opportunities available, as does the presence of many trophies such as Japanese glass fishing floats; but nothing is known about the extent of this activity. With the large boating population of southeast Alaska, boats from the lower 48 States included, seeking trophies along the beach must be an important part of the recreation experience here as it is in other coastal areas of the country. As access to remote beaches is made easier, this type of recreation is certain to increase.

Mountain Climbing

About 5 percent of southeast Alaskans reported mountain climbing in 1967 (table 12), but little is known about the nature and extent of this activity. By standards of the lower 48 States, the opportunities are ample and exciting; but peaks to the north--particularly McKinley--are probably more attractive to skilled mountain climbers from the lower 48. Some climbers from the Anchorage and Fairbanks areas are, however, reported to come to southeast Alaska to climb the icefields and peaks.

Other Dispersed Recreation Activities

Motorcycling, horseback riding, bicycling, and swimming are other activities in which southeastern Alaska residents reportedly engaged (table 12). At least two common activities were both omitted from the survey on which table 12 is based--berrypicking and beachcombing. Motor vehicle registration (table 3) indicates that the potential for motorcycling exists in some areas. But the amount of recreational use outside the communities, on backroads or trails, is unknown. Little information is available on the importance of horse use, bicycling, or swimming in dispersed areas. Lack of appropriate facilities and short summers may limit the extent of such activities, however.

Developed Recreation Activities

Although recreation activities in developed areas are usually more observable than those in dispersed areas, data concerning the amount of developed recreation in southeast Alaska are not much better than for dispersed forms. In many cases, it is impossible to distinguish between the two.

Table 22 gives information concerning recreation use of developed sites on the Tongass National Forest for 1975. Table 23 shows use of developed State Park sites. Other data for this section are shown in tables 12 and 15. An interesting fact emerges from these figures; less than 15 percent of the total estimated recreation use is on developed sites--207,900 days (table 22) compared with 1,133,200 days in dispersed areas (table 16).

Possible explanations for this relationship are: relatively few developed areas exist on the Forest; there are abundant dispersed areas which users prefer to visit; or a combination of both factors. An analysis of existing State Park, National Park, and Forest Service use figures gives the following picture of the major types of use of developed sites.

Table 22--*Use of developed recreation sites on the Tongass National Forest, 1975*

Type of developed site	Visitor-days[1]	Percent
Campground	88,100	42.3
Interpretive sites:		
Major	40,000	19.0
Minor	23,300	11.0
Winter sports	17,300	8.3
Picnic	12,600	6.0
Recreation residence	11,700	6.0
Organization:		
Forest Service	400	.2
Private	11,100	5.3
Play, park, sports	700	.3
Observation	1,300	1.0
Hotel, lodge, resorts	700	.3
Boating	700	.3
Total	207,900	100.0

Source: U.S. Forest Service Recreation Information Management (RIM) data, Alaska Region, Juneau.

[1] Recreation use of National Forests is measured in visitor-days. One visitor-day is defined as 12 visitor hours which may be any combination of numbers of people and time spent (e.g., 1 person for 12 hours or 12 people for 1 hour).

Table 23--*Number of visits to State Parks in southeast Alaska, by type of developed site, July 1, 1973, to June 30, 1974*[1]

Type of site	Resident		Nonresident		Total	
	Number	Percent	Number	Percent	Number	Percent
Campground	4,634	19	19,280	81	23,914	100
Picnic area	15,162	75	5,094	25	20,256	100
Historic site	14,165	31	31,742	69	45,907	100
Total	33,961	--	56,116	--	90,077	--

Source: State of Alaska Department of Natural Resources, Division of State Parks.

[1] Visits are defined as the entry of an individual for recreation purposes.

Campgrounds

In the 1937 study of recreation in southeast Alaska, little camping "for the sake of camping" was reported (Cameron et al. 1938). The situation seems very different today. Over a third of southeast Alaskan residents reported they camped in 1967 (table 12). Use figures from State and Federal agencies indicate that there were more than 1,000 overnight stays at the campground at Glacier Bay National Monument in 1976 (table 15); that more than 23,000 visitors went to State Park campgrounds in southeast Alaska, more than 80 percent of whom were nonresidents (table 23); that more than 88,000 visitor-days were spent in Forest Service campgrounds (table 22). A total figure for campground use in southeast Alaska cannot be computed because of the various ways in which these agencies collect and summarize their data.

The distinction between resident and nonresident camping warrants comment. Although it is not possible to distinguish between residents and nonresidents for the Federal campgrounds, the State Park use figures indicate a relatively low use by residents. This is not surprising because most campgrounds are within only a few minutes' drive of residents' homes, at the end of the limited road system. Local residents seem to use these areas for overnight camping to a limited extent, but one study indicated that campgrounds receive extensive day use by residents who prefer to return home at the end of the day (see footnote 17).

The only information about nonresident campers was compiled in 1964 (State of Alaska Department of Natural Resources 1964). The University of Alaska report (see footnote 17) summarized and interpreted the results as follows:

> The now outdated 1964 "campers survey" showed that the average nonresident camper was middle aged, traveled as a member of a couple, in a vehicle, and was in professional or highly skilled occupation. It appears that this is still an accurate description of the camper. Since that time another distinct group could be included in the report. The age group between 18 and 25 years now appears to be traveling more extensively in Alaska than during the 1964 study. Usually they are traveling as a childless couple or with groups of friends. They travel either by car or rely on public transportation. Those traveling by car appear to have similar behavioral characteristics to the older couples traveling by car.

Data related to campground occupancy are not available, but one study indicated that facilities are adequate around communities with the exception of Haines and Juneau (see footnote 17). Observers at Ketchikan report that many tourists camp overnight in a grocery store parking lot. The reason for this is not clear since the nearby Forest Service campground is rarely filled to capacity. Lack of information about the campground, proximity of the parking lot to the ferry dock, or a preference for staying in town are all possible motives.

Picnic Areas

Most southeast Alaska residents picnic (table 12). Although many probably do so in dispersed settings, much picnicking occurs at the many nearby picnic areas. On the Tongass National Forest, more than 40,000 visitor-days were spent picnicking, 12,000 of this (30 percent) at developed picnic sites (tables 13 and 22). And as discussed earlier, some of the use reported at campgrounds was probably by resident picnickers rather than campers; how much is unknown.

State Park picnic areas received about twice the amount of use as Forest areas with about 75 percent of the use by residents. No information is available about picnicking at developed outdoor recreation sites operated by local government agencies.

Resorts

Resorts are located on the National Forest and at Glacier Bay National Monument. The Forest Service reported only about 700 visitor-days at the lodges in 1975 (table 22); and 9,983 overnight stays were recorded at Glacier Bay during 1976 (table 15), an increase from 7,655 in 1975. Little is known about the composition of these groups or their activities. It is believed, however, that while staying at the lodges on the National Forest, users primarily engaged in hunting and fishing and those at Glacier Bay went sightseeing.

Interpretive Sites

Use of interpretive sites in southeast Alaska seems to be an important activity for many people who want to learn more about the area's natural, historical, and cultural resources. No information is available about the proportion of southeast Alaskans who visit these sites because this was not a part of the 1967 statewide survey. But some useful information is available concerning recent use of interpretive sites.

The Forest Service reports that in 1975 more than 60,000 visitor-days were spent at developed interpretive sites (table 22). More than 60 percent of these were at major sites including the Mendenhall Glacier Visitor Center where 100,000 people are estimated to visit yearly.[23]

Nearly 46,000 visitors are estimated to have visited State Park historical sites in fiscal year 1974 (table 23). National Park Service figures indicate that more than 81,000 visitors saw the interpretive displays at Sitka National Historical Park in 1976 (table 15). Interpretive contacts at Glacier Bay exceeded 64,000 visitors during 1976.[24]

Southeast Alaska has a unique type of "developed interpretive site"--the tourships and ferries, on which trained personnel explain the many features of the area. The U.S. Forest Service, under a cooperative program with the Alaska Division of Marine Transportation, runs the program on the State ferries traveling the Alaska Marine Highway; during 1976, more than 160,000 people attended the 1,893 programs provided.[25]

The National Park Service provides several interpreters for each tourship as it cruises through Glacier Monument. Over half of the more than 46,000 tourship passengers in 1976 took the opportunity to attend the formal programs provided.

Winter Sports Areas

Few developed winter sports areas exist in southeast Alaska. Forest Service figures indicate that about 17,000 visitor-days were spent at developed ski areas in 1975 (table 22), about 23 percent of the total amount of winter sports activities (including snowmobiling) reported for the entire Tongass National Forest (table 13).

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[23] USDA Forest Service. Alaska Forest data. Alaska Region, March 1976.

[24] Superintendent, Glacier Bay National Park (annual public contact report).

[25] This number exceeds the total number of passengers during this period (103,000+) because some people attended more than one program (USDA Forest Service. 1976 Season Summary for the Marine Highway Interpretive Program, Alaska Region).

SEASONALITY OF RECREATION ACTIVITIES[26]

The high degree of seasonality shown by the tourist inflow data presented earlier suggests when most nonresidents would engage in recreation activities. Results of the 1967 statewide survey of resident recreation participation show similar patterns. Although the patterns described in that report are based on tourists to all of Alaska, patterns of tourists to southeast Alaska would not be expected to vary significantly. Three seasonal activity patterns were observed:

1. Activities that occur predominantly during the summer season (May through September) include hiking, berrypicking, beachcombing, camping, mountain climbing, picnicking, fishing, boating, bicycling, and motorcycling.

2. Predominantly winter season activities (October through April) include winter sports--skiing, snowshoeing, snowmobiling, etc.

3. Participation in other activities is spread throughout a large part of the year; nature study and walking for pleasure (April through October); hunting (mainly August through November, but some continues all year); and driving and flying for pleasure in which participation occurs all year (weather permitting).

With the exception of walking for pleasure and nature study, participation occurs primarily on weekends; 60 percent of the walking for pleasure and 50 percent of the nature study takes place during the week.

VARIATION IN ACTIVITIES BY AREA

It would be unlikely for participation in recreation activities to be equally spread throughout all areas of southeast Alaska. Many factors influence the distribution of use, including the availability of opportunities (examples include winter sports areas, good fishing, big game populations, roads, and trails) and the proximity and size of potential user populations, i.e., residents who live nearby and tourists who arrive by plane, ship, or car.

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[26] Brent and Goldberg (1970) discussed the problems this seasonality presents in terms of the Alaskan tourism industry.

In table 13, use for various recreation activities within the three management areas of the Tongass National Forest is shown. Two examples will illustrate how this information can be used.[27]

Winter sports activities, including snowmobiling, were recorded primarily in the Chatham area (81 percent). Reasons for this include better snow conditions because this is the most northern area, large resident user populations compared with other areas, and the presence of more developed winter sports facilities.

Waterfowl hunting occurs predominantly in the Stikine area (78 percent). The area is noted for high quality waterfowl hunting.

TRENDS

Attempts to project future demand and participation for various recreation activities have proved unreliable.[28] Information on future use is, however, important for effective management and planning. Analyzing trends is one approach for determining what to expect in the future (see footnote 15). In this section we will briefly summarize the little existing information about trends in tourism and recreation activities in southeast Alaska. The reader is cautioned, however, to review all the limitations of the data described earlier.

The increasing importance of recreation and scenic values in the United States has been well documented (Bureau of Outdoor Recreation 1973). Dispersed recreation in particular has seen more rapid growth than other forms. With many unique features including vast expanses of undeveloped lands, southeast Alaska is becoming increasingly important to residents and visitors who wish to enjoy the many possible recreation activities as well as to appreciate the esthetic appeal.

In 1881, the first excursion party of 80 people visited Alaska's Panhandle. By 1890, the number of visitors was in excess of 5,000. In 1974, more than 230,000 people entered Alaska, most of whom (70 percent) spent at least part of their time in southeast Alaska

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[27] For readers interested in more detail, this information is broken down by smaller geographic areas in the Forest Service RIM System, Alaska Region, Juneau.

[28] See the Alaska State Outdoor Recreation Plan (State of Alaska Department of Natural Resources 1970a) for a discussion of problems in forecasting future growth in recreation activities. It also describes the procedures used in forecasting use for various recreation activities in all Alaska.

(table 8).[29] So the increase has been substantial with the annual growth at about 15 percent from 1964 to 1973. Use of ferries on the Alaska Marine Highway has increased by over 60 percent since 1970 (table 24). (Note that table 24 shows total ferry passenger numbers; table 7 gave figures only for tourists using the ferries.)

Table 24--*Increase in use of the Alaska Marine Highway ferry system from 1970 to 1975*

Fiscal year	Cars	Passengers
	Number	
1970	36,333	138,227
1971	35,463	144,696
1972	37,628	156,102
1973	42,432	180,553
1974	44,034	193,023
1975	52,287	224,213
Total	248,177	1,036,814
	Percent	
1970-75	44	62

Source: State of Alaska Division of Marine Transportation.

Growth in resident populations in southeast Alaska is an indicator of the potential for their recreation and related activities. The estimated 1974 population of 50,000 is an increase of about 43 percent since 1960, representing an annual increase of nearly 3 percent (table 25).

The best available trend data showing what these potential users do in southeast Alaska are data from specific areas and sites where accurate records have been kept. Generally, information about use of dispersed recreation activities and areas (with the exception of public recreation cabins) is of questionable reliability and will not be discussed here except to say that the annual increase has been estimated at about 15 percent. Information about past and present use of some of the developed areas and sites reveals the rapid growth of recreation in southeast Alaska, some of which is summarized below. These increases probably indicate what is occurring throughout this region.

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[29] This estimate is based on all tour ship and ferry passengers plus half the airline and highway passengers.

Table 25--*Population trends and projections, southeast Alaska*

Year	Population (to nearest thousand)	Year	Projected population
1940	25,000	1980[2]	66,000
1950	28,000	1985[2]	85,000
1960	35,000	1990[2]	99,000
1970	43,000		
1974[1]	50,000		

[1] State of Alaska Department of Labor, "Current Population Estimates by Census Division."

[2] University of Alaska Institute of Social, Economic, and Government Research.

1. National Park Service records indicate that visits have increased from about 7,300 in 1966 to more than 84,000 in 1976, a 1,150 percent increase (table 26). They anticipate an annual increase of about 10 percent per year for the next several years. Visits at Sitka National Historical Monument increased from 15,500 in 1960 to more than 80,000 in 1976.

Table 26--*Recreational visits to two National Park Service areas in southeast Alaska*

Glacier Bay National Monument			Sitka National Historical Monument		
Year	Visits	Percent change	Year	Visits	Percent change
1966	7,372	--	1960	15,500	--
1967	12,238	66	1965	25,800	66
1968	13,382	9	1971	43,200	67
1969	16,048	20	1974	63,783	48
1970	27,940	74	1975	76,962	21
1971	25,708	-8	1976	81,624	6
1972	24,675	-4			
1973	35,961	46			
1974	41,528	15			
1975	71,968	73			
1976	84,945	18			
Average annual change		31	Average annual change		42

Source: Superintendents at each park.

2. U.S. Forest Service campground use increased from 28,600 visitor-days in 1973 (see footnote 15) to more than 88,000 visitor-days in 1975 (table 22). Public cabin use increased 48 percent from 1972 to 1975 (table 20).

3. Total passenger traffic on the White Pass and Yukon route railways (fig. 48) has increased by more than 80 percent since 1963 (table 27).

Figure 48.--The White Pass and Yukon Route winds its way to Lake Bennett. Total passenger traffic has increased by over 80 percent since 1963.

Other data could be compiled to establish trends related to the amount of recreation in general as well as specific recreation activities, for example, boat sales, gasoline sales at marinas, use of local facilities such as motels and museums, and hunting and fishing license sales. The conclusion drawn from the data presented here, however, is that recreation use in southeast Alaska is increasing, rapidly in some cases.

Although specific, reliable trend data for dispersed recreation areas and activities are not available, the importance of those activities cannot be ignored. On the National Forest alone, they are estimated to represent more than 1 million visitor-days (table 16). And, if the estimated 15-percent annual increase is accurate, then an additional 150,000 visitor-days will occur in 1976.

Table 27--*Traffic by White Pass and Yukon route, 1963-73*

Year	Skagway to Whitehorse	Whitehorse to Skagway	Skagway to Bennett (round trip)	Skagway to Carcross (round trip)	Rail local	Total
			Number of passengers			
1963	3,802	3,551	2,201	18,525	989	29,068
1964	4,114	3,122	2,569	17,927	947	28,679
1965	4,572	3,461	4,701	6,202	492	19,428
1966	6,692	5,485	6,096	8,044	725	27,042
1967	6,056	5,923	3,822	6,233	474	22,508
1968	10,472	9,004	7,116	8,756	1,116	36,464
1969	11,563	9,513	18,858	--	958	40,892
1970	6,148	5,242	14,480	--	547	[1]26,417
1971	11,511	10,190	18,721	--	1,201	41,623
1972	13,612	11,624	15,582	--	1,820	42,638
1973	16,165	14,014	20,520	--	2,014	52,713
			Percent			
Increase	425	394	932	--	203	81

Source: Barron and Casavant. Economic Impact of Proposed Klondike Gold Rush National Historic Park on Skagway, Alaska. 1974.

[1] Labor strike from July 7 to August 17.

FUTURE INFLUENCES

What the future holds for outdoor recreation and esthetic values in southeast Alaska is hard to predict. There are many important influential factors related to both the supply of opportunities and demand for them that have great potential for change in the next few decades. How they will change is often unclear, and there appear to be some powerful cross-currents.

In this section we will identify some major factors, possible changes in them, and their likely effects. There is an important need for better information on the factors described and future changes in them; monitoring change as it occurs would be valuable.

FACTORS AFFECTING SUPPLY

1. The supply of outdoor recreation opportunities and scenic resources can be affected by changes in land jurisdiction or ownership. Access could be affected and the type of future development altered depending on who manages what types of lands, where they are located, and what policies are decided on for their management.

As specified in the Alaska Native Claims Settlement Act and amendments, each of the 10 recognized Native villages is entitled to select 23,040 acres (36 square miles) from Tongass National Forest lands. Selections must generally be made within the immediate vicinity of the villages--within 36-square-mile townships that are adjacent to or corner on the township in which the village is located, which is usually a block of nine townships (fig. 49) (Wilsey and Ham, Inc., McGaughan and Johnson 1973). One of the villages, Klukwan, is eligible to select lands well away from the village township areas. Juneau and Sitka Native groups will also select 23,040 acres each outside the boroughs. In addition, the southeast Alaska Natives' regional corporation (Sealaska) is eligible to select another 200,000 to 300,000 acres from the same general areas, and that organization can select any or all cemetery and historical sites. In total, these selection rights will reduce the size of the Tongass National Forest by about one-half million acres. The lands selected may be developed as the village governments and regional corporation decide. The regional corporation has a profit-making directive, however, but the villages do not. Possibilities range all the way from the development of resorts to clearcutting, with many intermediate alternatives. Gazaway (1964) indicated Native groups did not favor recreation development in their traditional areas, but the future course is unclear.

In addition, the State of Alaska is entitled to select up to 400,000 acres for community expansion and recreation from the Alaska National Forests, part of which will come from the Tongass National Forest. It also can select lands for the same purposes from public domain lands outside the National Forest (almost all in the Skagway area). Plans for these lands are indefinite now, although some State Parks and trail developments have been mentioned as possibilities.

2. Future economic developments have great potential for changing the supply of outdoor recreation opportunities on all lands of southeast Alaska. Extensive development could either alter the types of opportunities available along the recreation spectrum or reduce or eliminate certain types of opportunities entirely, a problem that has concerned many people and which was expressed by Marshall in 1937 (Marshall 1938, p. 213):

> When Alaska recreation is viewed from a national standpoint, it becomes at once obvious that the highest value lies in the pioneer conditions yet prevailing throughout most of the Territory.... In Alaska alone can the emotional values of the frontier be preserved.... Alaska is unique among all recreational areas belonging to the United States because Alaska is yet a wilderness.

   a. Logging and associated road development and log storage in bays have potential for modifying outdoor recreation resources and opportunities and for detracting from the

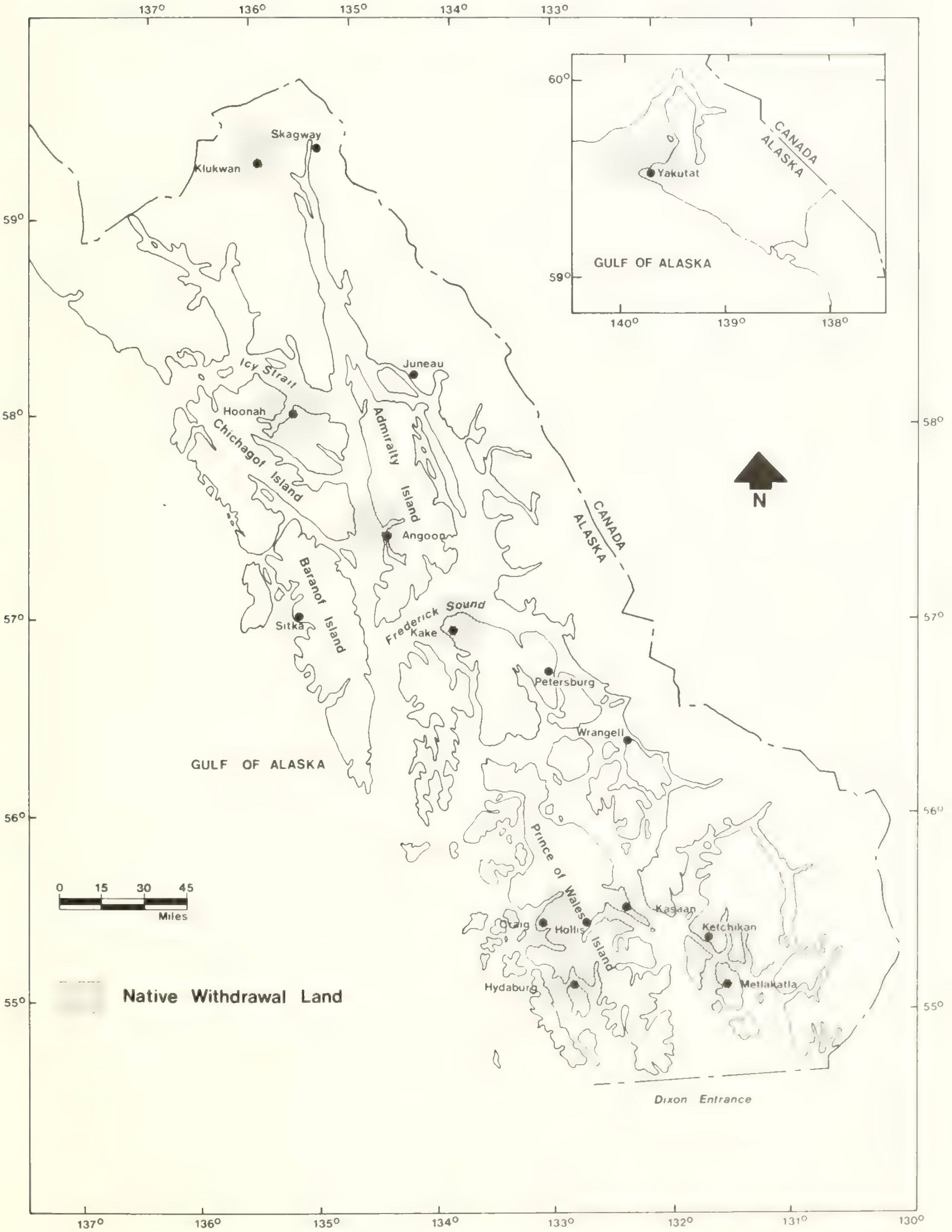

Figure 49.--General area of Native withdrawal lands in southeast Alaska.

appeal of the scenic resource (fig. 50). Since 1951, a series of four long-term timber sale contracts (50 years of timber harvest) totaling almost 22 billion board feet have been negotiated on the Tongass National Forest (fig. 36). In June of 1976, however, the Forest Service approved Champion International Company's request for cancellation of its long-term contract (8.75 billion board feet). The resulting effect will be to open up new options for the lands included in the contract areas, principally areas on Admiralty Island and the mainland south of Juneau. Whether these areas or parts of them will be included in future timber harvest plans is unknown at this time. The current land use planning process will consider a variety of alternative uses of these lands. The present allowable harvest level in Alaska's National Forests is nearly 900 million board feet (USDA Forest Service 1976), with about 91 percent of that from the Tongass National Forest. If the full allowable harvest is reached, cutting on about 30,000 acres will be required annually (Hutchison and LaBau 1975). The remaining long-term sales leave many specifics to be worked out in succeeding 5-year periods. Many smaller independent sales are also in progress or are planned for the future. Depending on what detailed plans are adopted, wildlife, recreational, and esthetic resources can be altered extensively. Unknowns include the specific locations of future cutting, whether tightly clustered or widely scattered; the location and type of roads and whether or not they remain open to public use; silvicultural methods used (clearcutting, shelterwood, or other methods); location of log storage areas; logging camp locations; and so on. All these factors have short- and long-run implications for recreation and scenic resources.

Widespread areas, roaded and developed largely as a result of logging, and those scheduled for cutting are many (fig. 36). And if market conditions improve, areas classified as marginal for timber harvest may then be considered for logging (Hutchison 1967).

In some areas, such as Prince of Wales Island, road systems are creating access to recreational opportunities of the kind commonly available in the lower 48 States but scarce in Alaska. Undoubtedly, the resulting road systems will have recreational value; but the desirable mixture of this kind of development and undeveloped, roadless opportunities is unknown.

The location of possible new timber processing plants could also alter recreation opportunities in their vicinity.

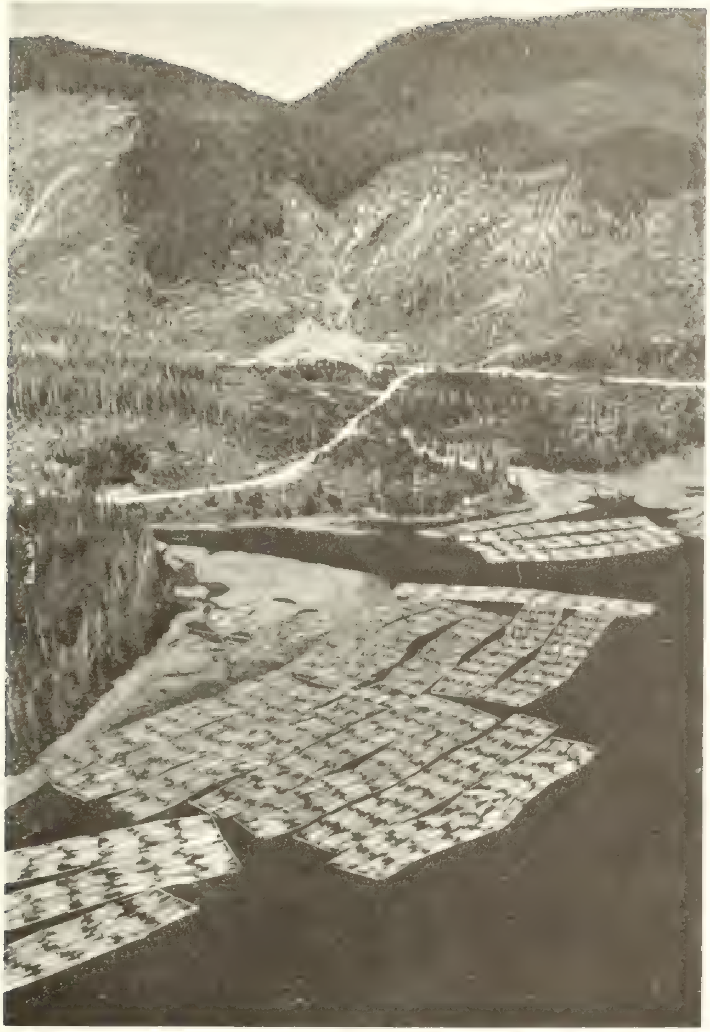

Figure 50.--Recreation and esthetic resources can be altered extensively by a variety of factors including log storage areas in marine bays.

if the plants are located outside the existing communities in undeveloped country.

b. Hydroelectric power developments are presently limited, but steep streams and heavy precipitation provide sites for dams and generators, especially on the mainland. Over 80 areas have been identified and reserved for possible development (Resource Planning Team 1975). Future developments could affect scenic resources and wildlife. The resulting manmade lakes would probably be small because the steepness of the terrain would offer limited recreation potential. Although impact of the dams would be confined to relatively small areas, powerlines and associated roads may have a significant impact on the visual resource.

c. Geothermal resources are substantial (Resource Planning Team 1975). Natural hot springs are common and are evidence of the geothermal potential. Geothermal areas are located near Wrangell, Ketchikan, Sitka, and Hoonah, where markets for power exist. Development would hinge on further improvement of geothermal power generation technology that might alter relative costs of alternative power sources. It appears that outdoor recreation impacts of geothermal development would not be severe, and probably less negative than hydropower developments.

d. The Alaska Panhandle has a long, colorful history of mining, and much of the early settlement was motivated by prospecting and mining activity. Mining has subsided to a low level. But, is substantial mining only part of past history, or could it rise again? Mineralized areas are extensive and claims abound--as many as 10,000 on National Forest lands. A very wide range of types of minerals are known to exist, including gold and silver, copper, lead, zinc, platinum, tungsten, nickel, cobalt, chromium, iron, molybdenum, antimony, uranium, palladium, mercury, and others. Mining has been legally permissible in Glacier Bay National Monument (one of only six units in the National Park Service where mining is permitted), and there has been significant filing of mining claims and continued prospecting in that area (Jettmar and Summers 1975). Public Law 94-429, passed in 1976, closed Glacier Bay and the other National Parks to new mining claims; and existing claims will be considered abandoned unless they are refiled with the Secretary of Interior by September 28, 1977. There is a 4-year moratorium on any new surface disturbance on valid claims, and the requirement for annual assessment work has been suspended. Congress intends to make a decision on the future status of mining during the 4-year moratorium. Future needs and technological change make this another uncertain element. With so many different minerals present, the chance of enough increase in value to trigger development seems quite real. For example, a molybdenum mine is expected to open near Ketchikan in the early 1980's. Mines and mining roads could adversely affect recreation and scenic resources.

Increasing resource development and even increased recreation use have potential for reducing the rich cultural heritage of southeast Alaska. Protection of cultural and historical areas and artifacts was identified as a major problem as early as 1937 (Cameron et al. 1938). It is even more so today with increasing timber harvest and recreational use in areas where artifacts of prewhite and more recent civilization occur. The Sealaska Native Corporation reports increasing loss at known sites from sale of artifacts, negligence, and vandalism. Native heritage is important not only to people within the Native community but also to all citizens who might wish to appreciate the rich past culture of the Tlingit and Haida Indians. The problems in identifying the significance of this irreplaceable part of our history and in preserving it deserve prompt attention by land managers and the public. A start has been made in several agencies; for example, an archeologist in the Forest Service Regional Office in Juneau is working with interdisciplinary planning teams to identify and protect cultural sites. State law also protects antiquities.

FACTORS AFFECTING DEMAND

1. Local population change could alter recreation demands. The population of the panhandle is small but it is growing very fast (table 25). Population is projected to continue to grow rapidly, almost doubling in the next 15 years. Population projections are unreliable, however, and only the future will determine what will actually happen. The possible move of the State capital from Juneau could have a negative impact on the Juneau population, for example.

2. Change in demand by tourists from the lower 48 States depends less on population change (projected to grow slowly) than does change in demand by residents. Several other factors enter in, however. Growth in per capita income is one factor--visits to Alaska are expensive and rising incomes could result in increased visitation. Likely reductions at the more dispersed, less-developed end of the opportunity spectrum in the lower 48 States could produce a shift to Alaska of visitors who prefer such experiences. Changes in attractions in southeast Alaska such as the new Klondike Park and any new Wilderness Areas could alter use of those areas and of the region in general. More aggressive and widespread promotion and marketing of southeast Alaska outdoor recreation attractions also might increase tourism substantially. (For examples, see Spring and Spring 1967, Sunset Magazine 1976, Garret 1965.)

3. Changes in access to southeast Alaska could have a large effect on tourism, and changes in access within southeast Alaska could affect the distribution and amount of recreational use by both local residents and tourists. Improved highways in the rest of Alaska and Canada (particularly paving of the gravel portion of the Alaskan highway) might bring more people to southeast Alaska. Although the issue is presently dead, there have been proposals in the past for an extensive system of highways along the major islands of the Alexander Archipelago with short, connecting ferry links. Such a development, even in part, could totally alter recreation demand, as well as the nature of the recreational opportunities available. Several new ferry stops have also been proposed which would change use patterns within the area.

Long-range technical progress in air and sea transportation could lower real costs, reduce travel time, and increase recreational demand in the panhandle. Or, in contrast, rising energy costs could have the opposite effect and could make travel more costly, and, for all practical purposes, could make Alaska more remote and lightly visited than it is now. Which type of change will predominate is critical for shaping future recreation demand, but it cannot be predicted.

This last dilemma symbolizes the range of uncertainty and the fact that many of the forces affecting southeast Alaska originate far from the panhandle. Recreation supply and demand can be influenced by developments as remote as the cost of oil from Arabia or the price of woodpulp in Japan.

RECREATION ISSUES AND POLICY ALTERNATIVES

Conflicts between resource uses are certainly not unique to southeast Alaska; but they seem particularly apparent here because of major concentrations of important resource values and man's activities along the shorelines. This problem is identified by the Forest Service in the Tongass National Forest Guide as well as in the draft land use plan that preceded it. The draft land use plan stated:

> The shoreline, where land meets the sea, is the focus of man's attention. The land adjacent to the shoreline is the area of greatest activity and has the highest concentration of values on the Forest. It contains the nesting trees of the bald eagle, much of the spawning grounds of the salmon, and the essential winter range for the deer. It contains some of the most productive soils and some of the most economically accessible stands of timber. The greatest amount of recreation use occurs here.

So the stage was set many years ago for almost unavoidable conflicts on the National Forest lands in southeast Alaska, and today, emotions run high about what the appropriate uses of those treasured resources are. The intensity of emotional feelings is illustrated in the following statement by the Alaska State Parks Division about future logging, "A major concern of many Panhandle Alaskans is that things are happening in southeast which will tarnish those qualities which create such prime outdoor recreation opportunities, which will erode their source of livelihood, and shatter their cherished lifestyle."[30] Other writers have raised similar concerns (Shepard 1976, Evans 1969).

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[30] Proposed revision of the Recreation Section in the Alaska State Parks Master Plan, State of Alaska Department of Natural Resources, Juneau.

In southeast Alaska, impacts from resource use (principally timber harvesting) are not spread evenly over the 27 million acres of land. Further, they are not even spread evenly over the 16 million acres of the Tongass National Forest where most of the forested land is found. Impacts are concentrated at the shorelines and forested river villages where a combination of conflicting national, State, local, and individual life style values are focused (fig. 51). And with increasing demand for both wood fiber and recreational and scenic resources, conflicts are increasing rapidly. In 1937, the Resources Review Commission recognized this concern and said, "The Forest Service will take special precautions...to protect scenery along principal steamship routes" (Cameron et al. 1938). With the increasing importance of tour ships, recreational boating, and a variety of dispersed recreational activities on and off the principal routes, this problem is even more widespread and urgent today.

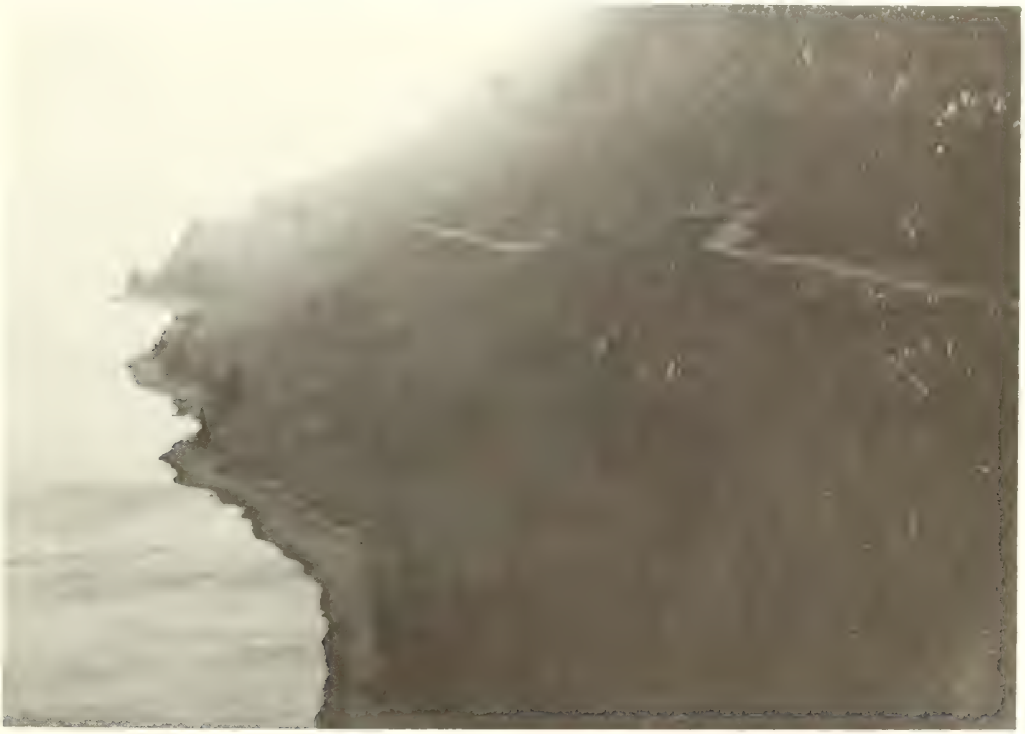

Figure 51.--Impacts from resource use are concentrated at the shoreline where a combination of conflicting values are focused.

Because of the increasing conflicts, it is important that choices of outdoor recreation goals for southeast Alaska be made. Widely divergent futures are possible. There have already been major changes since the ORRRC Report on Alaska appeared in 1962. Some of these changes may limit the available options, such as much heavier recreational use, more widespread logging and associated roads (which, although they have directly affected relatively few acres so far, have nevertheless altered the character of large areas along the sensitive shorelines), extensive timber sales (both long-term and short-term), the growth of the Alaska State ferry system, a great increase in tour ship numbers, a new visitor center at the Mendenhall Glacier and another at Sitka National Historical Park, new development at Glacier Bay National Monument, establishment of the Klondike Gold Rush National Historical Park, new public cabins, the appearance of snowmobiles, and so on.

Many of these changes, as they have affected outdoor recreation, were unplanned, unintended, and unexpected. Furthermore, there has been little evaluation of their effects. This is a problem not only in southeast Alaska but nationally as well. Recreation goals have not been clearly identified for National Forests until recently. As part of the Resources Planning Act, managing the National Forests for dispersed recreation will be emphasized (relative to developed types of recreation opportunities) in the future. Efforts are also underway at the national level to provide more specific direction about the National Forests' role in recreation across the entire recreation opportunity spectrum.

The National Park Service must also struggle with difficult decisions that determine the balance between its dual goals of protecting resources unimpaired and of providing for their enjoyment and use.

Experience elsewhere indicates how difficult it is to eliminate or reduce inappropriate uses once they have been established, and how much more acceptable are decisions on appropriate uses before they become established and evolve into vested interests. Examples from other parts of the country are plentiful: Summer home leases issued 40 to 50 years ago on what are now prime, public use areas are being terminated, but only slowly and painfully. Mechanized recreation (all-terrain vehicles, snowmobiles, motorboats) are being phased out of some areas where they do not fit, amid intense controversy. Public ownership of portions of shorelines in places like Lake Tahoe is being recovered at great cost.

The point is simple: Long-range planning before more commitments are made and patterns established can pay enormous dividends. As pointed out in an earlier report in this series about southeast Alaska, "the single most important problem is resource planning" (Harris and Farr 1974, p. 85).

Some progress has been made in expanding our knowledge about recreation and scenic resources in southeast Alaska. In 1937, the

Resources Review Commission recognized that the Forest Service "has not had sufficient opportunity to survey recreation possibilities in Alaska" (Cameron et al. 1938, p. 137). Today, combined efforts by the various agencies concerned with recreation potential in this area tell us quite a lot, much of which has been summarized here. But these efforts have not included detailed inventories of specific areas in the region for their recreation and scenic potential. Further, although we know quite a lot about potential opportunities, information related to use of them is scarce. Effective planning and management will require knowledge about both.

Five major issues stand out in any long-range planning related to recreation and esthetics: (1) protection of areas with high potential for recreation and scenic resource use, (2) interrelations of other resource uses and recreation-scenic values, (3) the desired mix of outdoor recreation opportunities, (4) coordination between the various recreation suppliers, and (5) adequate funding for recreation planning, development, and management.

1. The first issue, the need for protection of areas with high potential for recreation and scenic resource use, was described well by the Bureau of Outdoor Recreation in 1973 (page 27):

   > Some of America's natural resources need special consideration for their high recreation potential or their need to be protected. These are areas of great value to outdoor recreation on which uncontrolled development could result in irreversible damage to historic, cultural, or esthetic values, or natural systems or processes. Examples include coastal zones and estuaries; shorelines and flood plains of rivers, lakes, and streams; islands; rare or valuable natural areas; and scenic or historic areas.

   Although this statement was made about the entire Nation, implications for the importance of southeast Alaska as a supplier of such opportunities is obvious; the resources described are abundant in southeast Alaska and most are under Federal ownership.

2. Interrelations of other resource uses and recreation-scenic values applies mainly to timber harvesting, although mining and associated roads, docks, and processing plants could have major impacts in the future. Most of the other resource uses generally apply to relatively small, isolated areas; but logging covers large areas, changes access, may alter fish and wildlife habitats, may destroy historical or cultural sites, and affects scenery, generally adversely, at least in the short run--clearcuts in southeast Alaska require at least 10 years to really green up (Baugh 1976, Harris 1974).

   The usually rather uniform forests and the steep land exposed to view from the waterways make the planning of harvesting areas difficult. But progress is being made and future planning can produce further improvements. Landscape architects' professional skills are now being applied in inventorying and evaluating the visual resource and the layout of cutting units to create more attractive openings, more in harmony with the natural scale and texture of the landscape (Burke 1975). Issues of logging location, whether logging should be modified or deferred,[31] whether to group or scatter logging units, whether roads should be open to public use, and protection of fish and wildlife habitat are all critical issues that will need much careful future planning.

A key issue is determining the appropriate balance between use of land for production of timber or other commodities and recreation and scenic resource use; there are difficult challenges in reconciling differing national, regional, and local values and in working within the framework of each Federal and State agency's basic charter derived from legislation and policy. For example, the Alaska State constitution calls for resource use consistent with public interest, which State officials feel must include recognition of recreational and scenic resources in balance with commodity production, as shown in testimony on the National Forest Management Bill (U.S. Senate 1976). The National Park Service from its inception in 1916 has had a dual responsibility to protect natural conditions while providing for the use and enjoyment of the National Parks. The Forest Service mission, as defined in a series of legislation including the Organic Act of 1897, the 1960 Multiple Use-Sustained Yield Act, the Wilderness Act of 1964, the Endangered Species Act, the Forest and Rangeland Renewable Resources Planning Act of 1974, and the National Forest Management Act of 1976, is to strive to manage the National Forests for a balanced combination of uses that will best meet the needs of the American people. The problem for all these agencies is defining the balance needed in a constantly changing world.

3. The desired mix of outdoor recreation opportunities is a key decision, and one that really has not received as much attention as the integration of logging and recreation-scenic values. The choice is not all or none of one kind of opportunity, but how much of each type of opportunity along the spectrum to provide. Again, balance is the issue. It is imperative to make decisions soon about the types of opportunities to be featured, by which agencies, and the relative emphasis on each type of opportunity. If this is not done, the present distribution will surely shift due to ongoing management, perhaps in desirable ways, and perhaps not. Again, experience elsewhere indicates that as the

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[31] See the Tongass National Forest Guide and the draft Tongass Land Use Plan for a discussion of alternative schemes and special area designations.

nature of recreation opportunities changes, use will continue and often grow. Most visitors will still appear generally satisfied. This, however, can be misleading in terms of the desirability of the change. What is not obvious is that the visitors are often new, different people with different interests, and the former visitors have been displaced in an "invasion-succession" process (Clark, et al. 1971). The people whose desires and preferences are no longer met must seek other areas for their type of recreation, if they can. Most often the people who are bumped out are those who prefer more dispersed, less developed areas with more solitude. Finding areas with these characteristics is becoming more difficult. Southeast Alaska provides such opportunities in abundance and with superlative quality. A decision is essential as to whether, or to what degree, these dispersed opportunities will be maintained and managed.

Specifically, what is the need for classified wilderness in southeast Alaska? The Forest Service has identified six wilderness study areas (fig. 36) and will consider wilderness in planning management for other roadless areas. A coalition of conservation groups has proposed more than 40 areas for various types of protective classification[32] (fig. 52). There is doubt that the traditional air access and the cabins would be possible in classified wilderness, and some people believe that some other, intermediate, or back-country designation might be better suited to panhandle conditions. Or is some of both wilderness and back country needed? These are difficult and unanswered questions.

How much area is required for desired opportunities? Of what type? Where? What types of resource development and recreational activities are appropriate? Which are not?

The unique public cabins, which seem to fit the climatic conditions and brown bear situation of southeast Alaska so well, raise policy questions. How many cabins are appropriate? How isolated or widely spaced should they be? At what point can a lake support additional cabins? Where should cabins be located?

Roads pose many questions related to the mix of opportunities, most of which have already been discussed. New highways (such as the one from Carcross to Skagway) could drastically alter the character of large areas and the type of recreational experience

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[32] Southeast Alaska Conservation Council (SEACC). Response to the Tongass National Forest Land Use Plan. 1975. Decisions regarding the SEACC proposals are being made as part of the Forest Service planning process. Recent environmental impact statements, which call for logging and roadbuilding (including that in the long-term sale areas), affect more than 20 of the areas proposed for protective classification by SEACC.

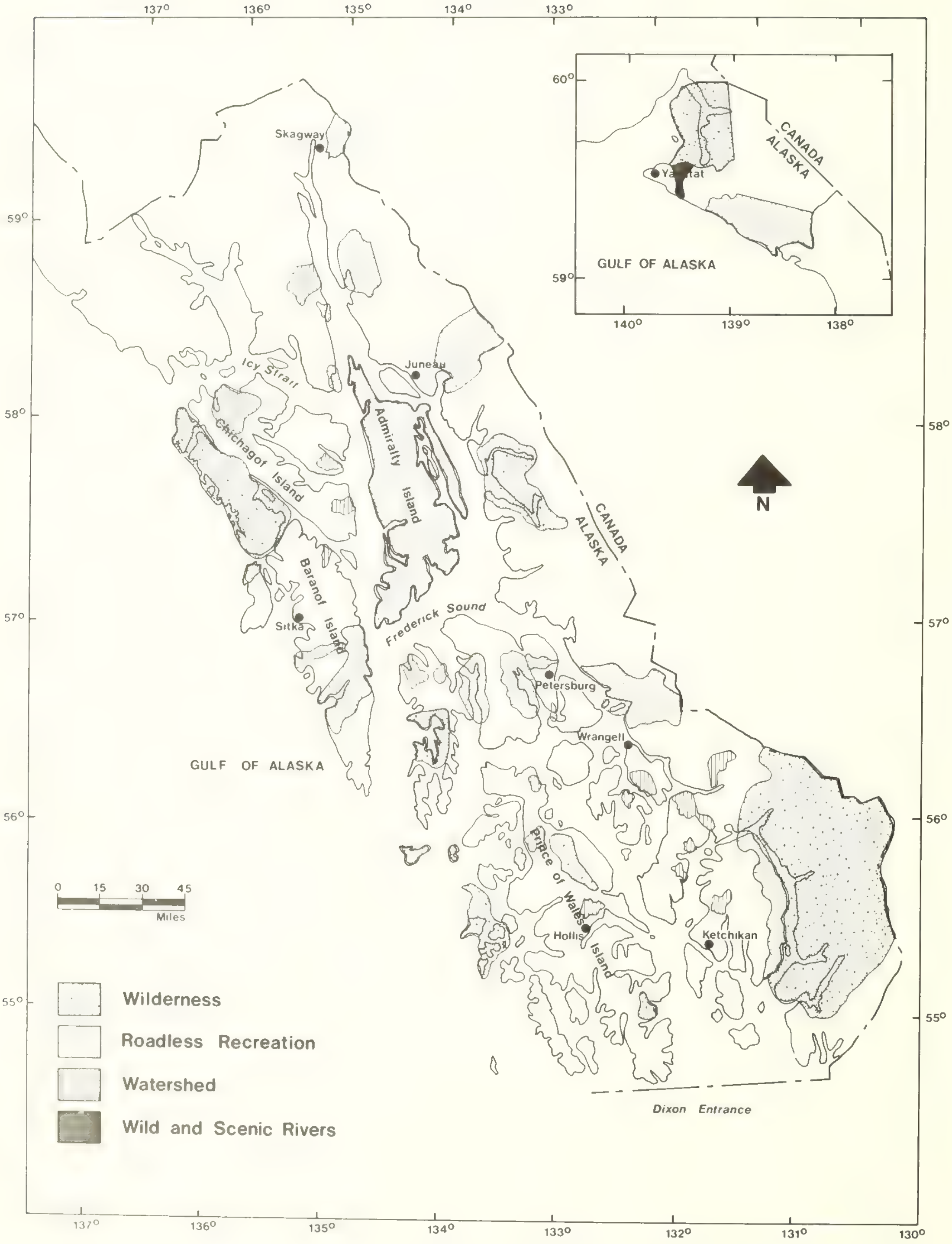

Figure 52.--Land designation proposals by the Southeast Alaska Conservation Council.

they offer. Logging roads, where they go, and whether they are open and will remain open for public use are critical questions. Road location can make it more difficult to protect historical and archeological sites. In addition, are there places where roads are desirable for recreation or scenic drives where logging and related roadbuilding will not occur?

What effect will decisions have on lifestyles of residents? How should local versus national recreation needs and values be balanced?

4. In the 1937 assessment of recreation in Alaska (Cameron et al. 1938), and again in the 1962 ORRRC reports, calls were made for coordination between the various recreation suppliers in Alaska. More recently, Thomas and White (1974) again stressed the "need to recognize common goals" and urged coordination. More than any time in the past, it is imperative that agencies with landownership responsibilities coordinate their efforts in planning, management, and data collection. Agencies and organizations without land jurisdiction responsibilities, but with interests in this area, should also be included. The specific roles each has in providing recreation and scenic resources need to be clarified and coordinated whenever possible.

   Coordination is a very different problem in southeast Alaska than in the lower 48 States. The overwhelming dominance of public land, especially the Tongass National Forest, and the largely self-contained nature of the panhandle--where other, outside alternatives are remote--set the stage in a unique way. These features have required the National Forest to play a role in meeting local needs that elsewhere would be the responsibility of local, county, and State agencies. This will probably change somewhat as State and Native village land selections become final. The role of the National Forest will still be great, however, and this places a heavy responsibility on the Forest Service to coordinate its recreation planning with other agencies.

   Recent events hold promise for the future. The National Forest has initiated efforts to strengthen its land use planning process and has involved other agencies and organizations in this effort. Recreation and scenic resources will certainly receive a great deal of attention--at local, regional, and national levels. Although final results will not be apparent for several years, the visibility of the process and the involvement of citizens are certainly keys to assuring that no important values are overlooked.

5. The four previous issues cannot be successfully resolved without adequate funding for recreational planning, development, and management. State and Federal funding levels for recreation management and planning in southeast Alaska are small and have

grown little in recent years. There is no easy answer to what an appropriate funding level would be for recreation in any State or Federal agency, or for any other part of a particular agency's program such as timber or wildlife management. This is not a problem unique to southeast Alaska. Resource managers in all parts of the country and at all levels of government are faced with the difficult task of arriving at an appropriate balance between resource programs which favor recreational and scenic values vs. those favoring production of commodity resources such as timber or mineral. With the values at stake, as described in such glowing terms by Bohn (1967), Muir (1915), Gannett (1904), and Marshall (1938), and pressures for utilization of some of these same resources, the issue of balance seems to be particularly important in southeast Alaska at the present time. Current land-use planning efforts, involving both local and national concerns, are intended to arrive at balanced programs with equitable funding levels for all resources, including recreational and scenic values.

RESEARCH NEEDS[33]

The preceding discussion on recreation and esthetic resources and their use in southeast Alaska identifies the need for research-based information in some critical areas. Effective planning and management of recreation resources and use will require reliable information not now available. Some of the general research needs are described briefly here. But for any research program to be useful, consultation with land managers during the problem analysis stage will be necessary to assure that research is responsive to planning and management needs. Coordination between the various agencies involved in recreation management and research in southeast Alaska will also be essential to insure comparable and useful data.

The problem areas identified below call for use of existing research technology to provide information regarding southeast Alaska's recreation and scenic resources and their use. Development of new methodology for studying recreation-related issues is important, but usually it can be done more efficiently outside of Alaska. In addition to the general problems for study listed below, many of the research needs discussed in other reports in the "Ecosystems of Southeast Alaska" series have relevance for recreation and scenic resources.

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[33] Recreation research needs for southeast Alaska are also discussed in an unpublished report, "Research Needs for Southeast Alaska," by John C. Hendee, available from the Pacific Northwest Forest and Range Experiment Station, 4507 University Way NE, Seattle, Washington 98105; in Yoesting (1975), and in Johnson (1977).

Gathering reliable baseline information regarding the amount and types of recreation use and users' attitudes, behavior, and perceptions is a basic research need. The data available are of questionable reliability and must be strengthened to allow for effective monitoring of trends and changes resulting from the future influences discussed earlier. Specific user populations (i.e., Native Indians, other residents, tourists, etc.) must be identified and their individual patterns of use and desires determined. This need is particularly apparent for the dispersed forms of recreation which are difficult to monitor. Better resource inventory data that can be used to support planning is also essential.

Other major problem areas requiring research include the following:

1. Economic impacts and trade-offs. What are the effects on local, State, and national economies from alternative resource development and recreation programs?

2. Physical and biological impacts of recreation use. What are the magnitude and importance of impacts related to recreation use and how might these impacts be controlled?

3. Needs, desires, satisfactions, and perceptions of local, State, and national clientele. Who is being served and who is not? Why? What impacts will increased resource utilization or tourism have on local or regional lifestyles?

4. Impacts on recreation and esthetic values from logging and other resources uses. What is the acceptable level and type of resource development such as timber harvesting and fish habitat management?

5. Availability of opportunities along the recreation opportunity spectrum. How is the distribution of opportunities being affected by current (and planned) resource development? Will increased tourism adversely affect the nature of the opportunities desired?

CONCLUSIONS

This paper has dealt with an assessment of the availability and use of recreational, scenic, and esthetic resources in southeast Alaska. We have also attempted to identify the interrelationships and conflicts between these resources and other resource values in this region, such as timber harvesting and mineral development. This analysis reveals that a range of possibilities exists for the future supply of recreational and scenic resources. The entire region is in a rapid state of change, however, which presents difficult challenges to resource managers and the local, regional, and national publics which they represent. There are a variety of forces at work, many in conflict with one another, and answers to the basic question of "what is the appropriate balance in resource uses?" will not be easy. But programs to effectively manage and protect the rich recreational, scenic, historical, cultural, and esthetic resources of southeast Alaska (many of which are unique) will require prompt attention and cooperation from all land managers.

The information available about the supply of recreational and scenic resources, and particularly the use made of these resources, is either incomplete or of poor quality. A major effort to provide the basic information required for planning and management purposes will be necessary to allow objective assessments of impacts related to resource uses of all kinds. Just as the use of the timber or mineral resources for commodity purposes will affect the distribution of certain types of recreational and scenic resources, so will a decision to provide recreational or scenic opportunities of one kind or another affect how we can use other resources for commodity purposes. Although better information will not tell us what is the proper balance, it will provide resource managers and the public with an improved basis for determining the relative impacts from the available alternatives.

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APPENDIX

COMMON NAME	SCIENTIFIC NAME
Plants	
alder, red	*Alnus rubra*
blueberry, Alaska	*Vaccinium alaskaense*
cabbage, deer	*Fauria crista galli*
cedar, Alaska	*Chamaecyparis nootkatensis*
redcedar, western	*Thuja plicata*
cottonwood, black	*Populus trichocarpa*
hemlock, mountain	*Tsuga mertensiana*
hemlock, western	*Tsuga heterophylla*
huckleberry	*Vaccinium parvifolium*
menziesia, rusty	*Menziesia ferruginea*
pine, shore	*Pinus contorta*
spruce, Sitka	*Picea sitchensis*
Animals	
Land	
bear, black	*Ursus americanus*
bear, brown	*Ursus arctos*
beaver	*Castor canadensis*
coyote	*Canis latrans*
deer, Sitka black-tailed	*Odocoileus hemionus sitkensis*
fisher	*Martes pennanti*
fox, red	*Vulpes vulpes*
goat, mountain	*Oreamnos americanus*
hare, snowshoe	*Lepus americanus*
lynx, bobcat	*Lynx canadensis*
lynx, common	*Lynx lynx*
martin	*Martes americana*
mice	Cricetidae (family)
mink	*Mustela vison*
moose	*Alces alces*
muskrat	*Ondatra zibethica*
otter, land	*Lutra canadensis*
porcupine	*Erethizon dorsatum*
shrew, common	*Sorex cinereus*
shrew, dusky	*Sorex obscurus*
shrew, northern water	*Sorex palustris*
squirrel, flying	*Glaucomys sabrinus zapheus*
squirrel, red	*Tamiasciurus hudsonicus*
weasel, short-tailed	*Mustela* sp.
wolf	*Canis lupus*
wolverine	*Gulo gulo*

Marine

clams	Mollusca (phyllum)
crabs	Brachyura (tribe)
halibut, Pacific	*Hippoglossus stenolepis*
herring	*Clupea harengus*
otter, sea	*Enhydra lutris*
rockfish	*Morone saxatilis*
sablefish	*Anoplopoma fimbria*
salmon, chinook (king)	*Oncorhynchus tshawytscha*
salmon, chum (dog)	*Oncorhynchus keta*
salmon, coho (silver)	*Oncorhynchus kisutch*
salmon, pink (humpback)	*Oncorhynchus gorbuscha*
salmon, sockeye (red)	*Oncorhynchus nerka*
scallops, mollusks	
sea lion	Zalophus and Otaria
seal, elephant	*Mirounga angustirostris*
seal, harbor	*Phoca richardii*
shrimp	*Natantia*
steelhead	*Salmo gairdneri*
trout, cutthroat	*Salmo clarki*
trout, rainbow	*Salmo gairdneri*
Dolly Varden	*Salvelinus malma*
whales	Cetacea (order)

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programs for road network planning

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Abstract

This paper describes four computer programs developed to assist logging engineers to plan transportation in a forest. The objective of these programs, to be used together, is to find the shortest path through a transportation network from a point of departure to a destination. Three of the programs use the digitizing and plotting capabilities of a programable desk-top calculator system to conveniently enter and store a numerical description of the network to be analyzed. The fourth program solves the problem by an efficient optimization algorithm. The BASIC language programs are described through an example problem, and complete listings are provided.

KEYWORDS: Road administration/planning (forest), transport system design (forest), computer programs/programing, computers (desk-top).

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Introduction

The determination of the shortest route (or path) through a network of available routes is often an important step in planning transportation. Although problems in finding the shortest route frequently arise in other disciplines (Bradley 1975), they are most commonly associated with road networks, and this paper will discuss these problems.

Since the mid-1950's, much attention has been devoted to problems of finding the shortest route. Recent publications have discussed procedures for solving such problems by hand (Mandt 1973, 1974) and by large, digital computers (Elsner et al. 1975, Martin 1963, Schnelle 1972). The Forest Service has recently adopted a network analysis system (Sullivan 1974), which is perhaps the most flexible system in existence, but it requires the availability of a very large computing facility.

The programs discussed in this paper fall into the middle ground between procedures intended for hand computation and those developed for large-scale computers. These programs were developed and tested on a Hewlett-Packard 9830 programable desk-top calculator and were designed to take advantage of the digitizer-plotter capability of that calculating system. The shortest path program itself, however, is quite general and could be used, without significant revision, on any calculator or computer that uses the standard ASCII (American Standard Code for Information Interchange) BASIC programing language.

Network Analysis

A transportation system (such as a system of forest roads) may be described as a *network*, a collection of interconnected segments or *links*. Each link describes a unique path between two adjacent *nodes*. A node is any feature that might be treated as the point of departure or destination of some path through the network, such as a landing or mill. Nodes may also be road intersections, viewpoints, scaling stations, and bridges. Nodes are also commonly used to indicate points at which road design standards change or there is a marked change in grade or curvature. Such changes would be expected to influence costs of hauling logs (Byrne, et al. 1960) and may therefore be of interest in the solution of many forest transportation problems.

Figure 1 is a map of a small but representative road network for a hypothetical forest. Nodes have been superimposed on the network at each landing, at two grade breaks, at one point at which the road standard changes, at a bridge, at each of the three road intersections, and at the destination (the mill). Numbering of these nodes is arbitrary. Each link, however, is referenced according to the adjacent nodes which it interconnects. Furthermore, links are commonly bidirectional. That is, link 1-2 is "different" from link 2-1, even though each represents the same segment of road. This is a useful distinction for differentiating the cost of hauling logs over an adverse grade in one direction and hauling them over a favorable grade in the opposite direction along the same link.

SHORTEST-PATH PROBLEMS

The specific problem addressed in this paper is that of finding the shortest path through a network from a specified point of departure. The unit of measure selected to judge a path's length can be almost anything. Common units are hauling costs, distance, or time; but other units, such as construction cost, maintenance cost, or even a measure of the scenic or esthetic value along the link, could be used. Although this problem would normally be solved for the shortest path between a specified point of departure and a

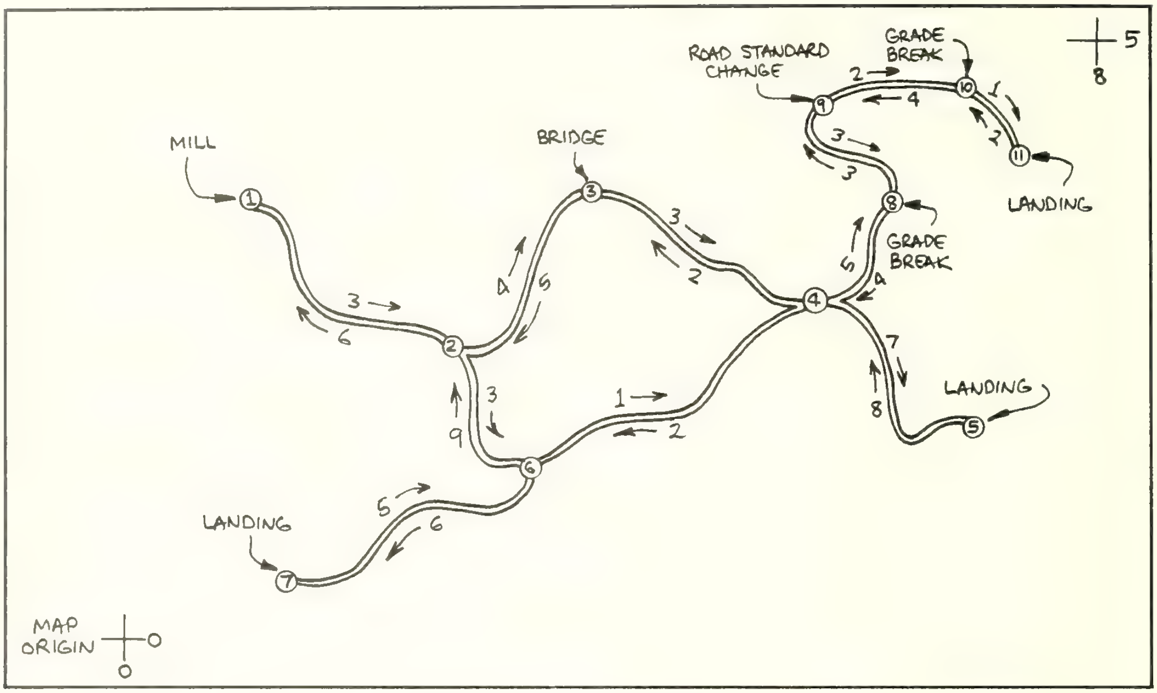


Figure 1.--Source map for the example problem.

specified destination, it may occasionally be of interest to solve the problem for all the shortest paths from the departure node to all other nodes. As an example, we might use this capability to solve for the best network of backhaul routes (i.e., when a truck is traveling empty) from the mill to all landings. The problem of finding all the shortest paths from a departure node to all other nodes is called the "*n*-shortest-paths problem." It seems that this problem would be much harder to solve than the simple shortest path problem, and several of the faster algorithms for solving the shortest path problem also find the *n* shortest paths at the same time (Bradley 1975). The solution procedure we have selected belongs to this class of algorithms. It is called the "Moore algorithm" and has been described fully by Martin (1963). Although it always determines the *n* shortest paths from a specified point of departure, our program permits the user to decide whether all *n* paths or only the single shortest path to a specified destination should be printed out.

Network Analysis Programs

The programs (to be used together) are of two types: three programs are of the first type; they essentially set up the problem by generating the network. The second type (the fourth program, "Optimization Program") solves the problem. The network generator programs are machine dependent; that is, they were developed specifically for the digitizing, plotting, and computing capabilities of the Hewlett-Packard 9830 system. Numerous other systems, however, have similar capabilities; the description in this paper is intended to be general enough that the programs can be converted to other systems.

PROGRAM LIMITATIONS

In their present form the programs can accommodate a maximum of 60 nodes and 255 links, with no more than 8 links (i.e., eight bidirectional paths) meeting at a single node. These limitations are a function of the calculator memory and could be increased if memory capacity were expanded. The calculator systems on which the programs have been developed and tested have the following configuration:

HP-9830 calculator with 15,808 bytes (7,904 words) of read-write memory

Additional read-only memories:
    plotter control
    extended input/output
    string variable

Flatbed plotter (9862A)
Digitizer (9864A)
Thermal page printer (9866A)

NETWORK GENERATOR

The most burdensome phase in network analysis by computer is usually data entry. Nodes and links must be identified and link values must be assigned before the analysis can begin. A primary advantage of the approach reported here is that the network definition task has been automated by the use of the HP-9830 digitizer.

Three network generator programs are provided for entering problem data into the calculator: one is loaded into the main memory of the calculator, and the other two are loaded into special function keys f_0 and f_1. Table 1 summarizes the input procedure for the data required when these programs are executed. Note that after all three programs have been loaded into the calculator, the program in main memory is executed first. This provides the user with some preliminary instructions and initializes certain internal memory locations. The program on special function key f_0, which enters the network via the digitizer and reproduces it on the plotter, is executed next. This program also computes and applies a "rotation factor" so that the user need not be concerned about whether the source map is correctly alined on the digitizer. After the network has been completely digitized, the program on special function key f_1 is executed. This program establishes a "link matrix" which identifies individual links by their "from" and "to" nodes. It also prints a link summary and permits the user to store the link matrix on a cassette tape if desired.

Figures 2, 3, and 4 summarize the printed output resulting from running the three programs listed above. This output is for the example program in figure 1, entered as shown in table 1. It is important to note that these tables contain printed output only. Numerous requests for data and certain instructions to the user are displayed (in the calculator display window) while these programs are running but are not printed. This convention produces a "clean" printout. A complete track of all printed and displayed messages, as well as a record of all inputs, can be obtained if desired by putting the calculator into "PRT ALL" mode before running the program.

In addition to the printed output, the program on key f_0 also plots the digitized network on the flatbed plotter (fig. 5). This plot is useful as a visual check to insure that the network has been correctly entered into the calculator.

SPECIAL CONSIDERATIONS

It should be evident from the example (fig. 1) that it is often necessary to re-digitize nodes which have already been digitized in order to correctly describe all routes of the network. As an example, consider nodes 4 and 5. Node 5 must be digitized after node 4, and then node 4 must be redigitized in order to continue the network. When this happens, the calculator is programed to sense that the node has already been digitized, and a message to that effect is printed (fig. 3).

Table 1--*Input explanation for network generator programs*

Visual prompt on display or printer (oral prompt by digitizer)	Keyboard or digitizer response	Explanation
	SCRATCH A.	Clear calculator memory.
	LOAD 5.	Load programs from tape.
	LOADKEY 4.	
	RUN.	Begin program execution.
DOCUMENT HORIZ.DIM. (INCHES)?	8.	Enter map dimensions.
DOCUMENT VERT.DIM. (INCHES)?	5.	
SELECT FUNCTION KEY (F0)	f_0.	Depress special function key f_0 to digitize network.
SET THE ORIGIN AT POINT 0,0 ON THE NETWORK SOURCE DOCUMENT (digitizer "beep")	Depress red "0" button on cursor.	Set point to which nodes will be referenced.
DIGITIZE POINT 8,5 ("beep")	Digitize upper right-hand corner of map.	Use "S" button on cursor.
START DIGITIZING NODE LOCATIONS BEGINNING WITH YOUR CHOICE FOR NODE #1 ("beep")	Digitize node 1.	Use "S" button on cursor to enter node locations.
("beep")	Digitize node 2.	
("beep")	Digitize node 3.	
("beep")	Digitize node 4.	
("beep")	Digitize node 5.	
("beep")	Redigitize node 4.	
("beep")	Digitize node 6.	
("beep")	Redigitize node 2.	Define link between node 2 and node 6.
("beep")	Redigitize node 6.	
("beep")	Digitize node 7.	
("beep")	Digitize map origin.	Use "S" button, not '0'; this informs the calculator that a new route is to be entered.
("beep")	Redigitize node 4.	Enter new route, starting at node 4.
("beep")	Digitize node 8.	
("beep")	Digitize node 9.	
("beep")	Digitize node 10.	
("beep")	Digitize node 11.	
("beep")	STOP.	Halt digitizer program.
	f_1.	Depress special function key f_1 to print a link assignment summary.
. . . (link matrix summary is printed)		
LINK MATRIX COMPLETE. STORE?	YES.	Indicate that the link matrix is to be stored on tape.
FILE # (MINIMUM SIZE =768)?	0.	Store link matrix on tape file 0.
. . . (program terminates)		

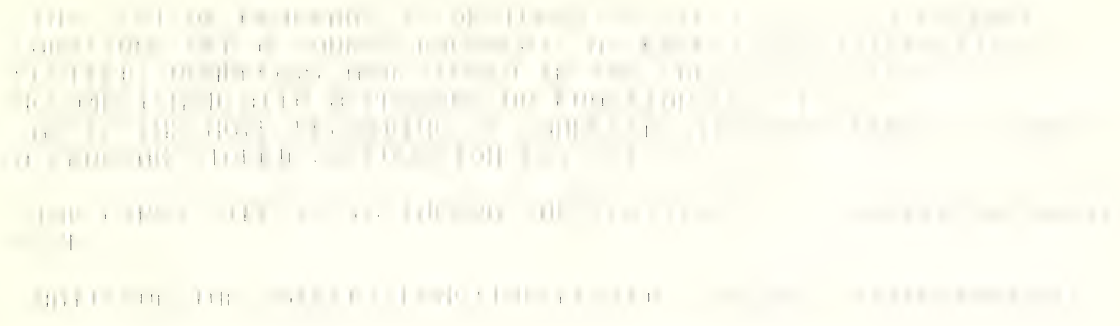
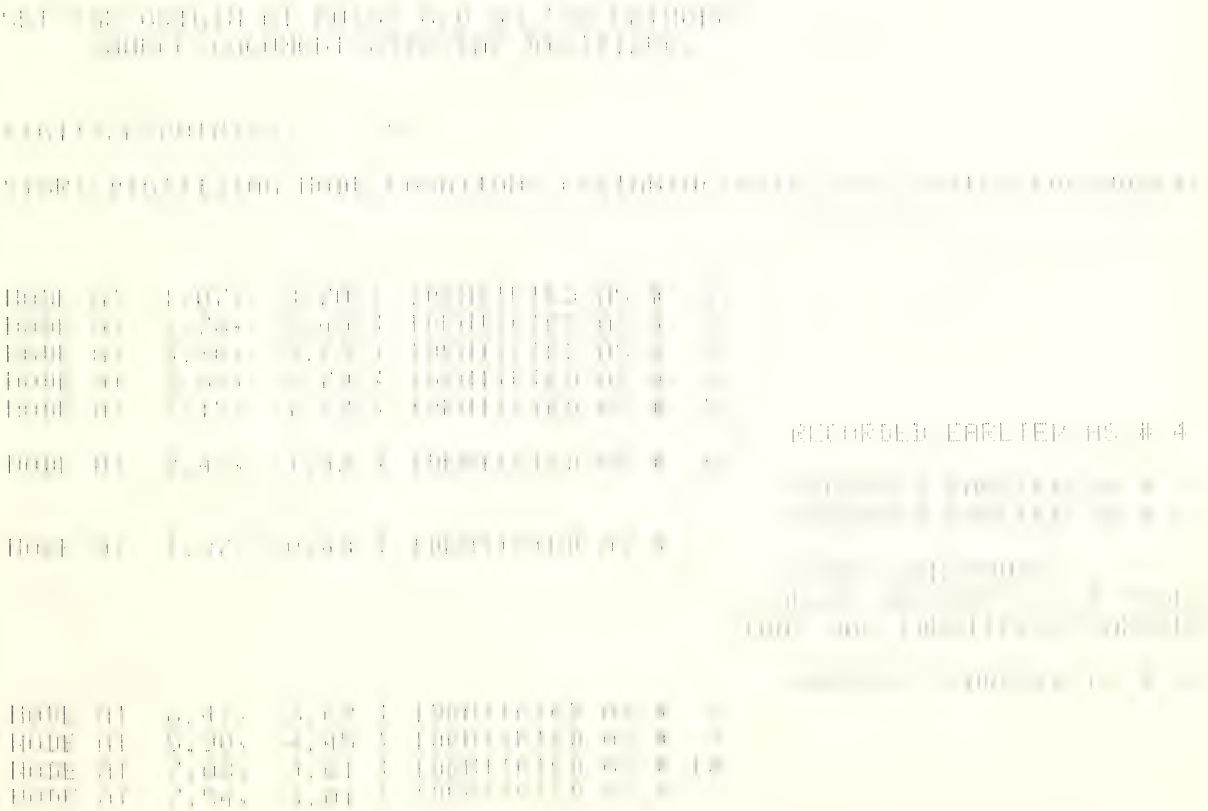
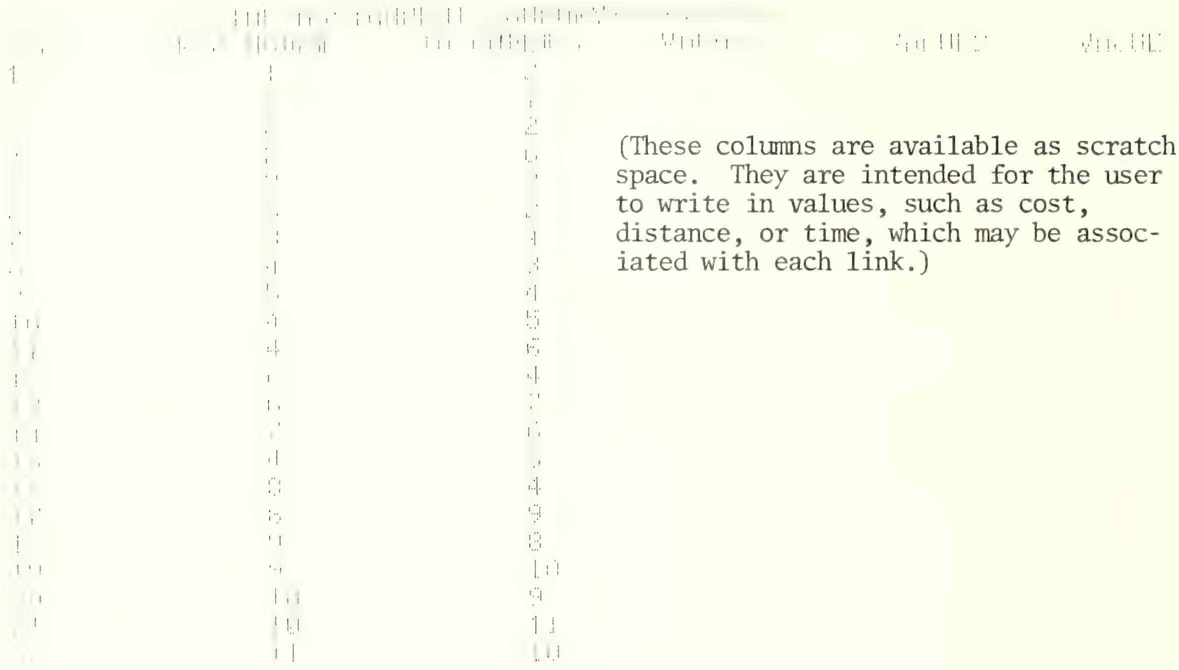


Figure 2.--Printed output from the program in main memory (loaded from tape file 5) for the example problem.



```
RECORDED EARLIER AS # 4
```

Figure 3.--Printed output from the program on special function key f_0 (loaded from tape file 4) for the example problem.



(These columns are available as scratch space. They are intended for the user to write in values, such as cost, distance, or time, which may be associated with each link.)

Figure 4.--Printed output from the program on special function key f_1 (loaded from tape file 4) for the example problem.

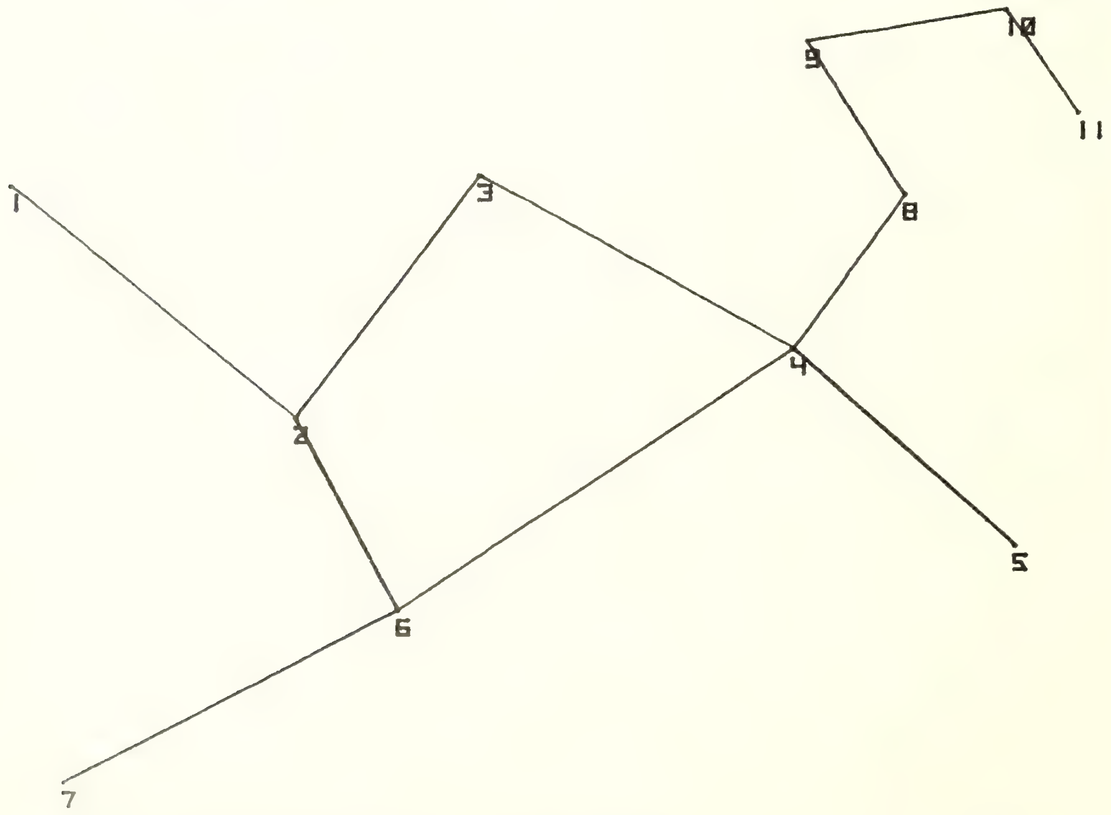


Figure 5.--Plotted facsimile of the network entered via the program on special function key f_0.

Occasionally it may be desirable to enter an entirely new route to avoid redigitizing several points. As an example, refer to the dead-end route leading from node 4 to node 11 (fig. 1). Rather than digitizing nodes 4, 8, 9, 10, and 11 and then retracing the route back to node 4, it is convenient to enter those nodes as a new route. This is done after all other nodes have been digitized. For example, the last node to be entered is node 7 (figs. 1 and 3). Then, the fact that a new route is to be entered is signaled by redigitizing the map origin (lower left-hand corner), followed by the nodes of the new route (4, 8, 9, 10, and 11). Any number of new routes can be entered in this manner.

OPTIMIZATION PROGRAM

After the network has been fully described, the calculator memory is cleared and the optimization program is loaded into main memory to solve the problem. The link matrix created with the network generator may then be loaded from a tape (if it was stored as indicated at the bottom of table 1). Otherwise, it can be entered at the keyboard. Although the latter capability may appear unnecessary, it has been included to permit users without digitizers to use the optimization program. Such users would simply enter the link matrix at the keyboard without having previously run the network generator programs.

Once the link matrix has been entered (either from a tape or through the keyboard), values must be associated with each link. These values can also be entered from a tape or through the keyboard. Link values might have been stored on tape after a previous run of the optimization program; normally, they will be entered at the keyboard. As shown in table 2, the calculator prompts the user by requesting each link value. After all values have been entered, the user is given the opportunity to change any of the link values, to add links, or to delete links. Either the link matrix or the value array or both may then be stored on tape if desired (see table 2).

The optimization routine begins after the user identifies the initial node, or point of departure (table 2). As discussed earlier, this routine finds the shortest paths from the initial node to all other nodes. The method used for the optimization is not discussed in this paper; interested readers are referred to a complete discussion of the Moore algorithm (Martin 1963).

When the optimization is complete, the calculator requests the number of the terminal node (see table 2). The user may then indicate a specific node, in which case the shortest path from the initial node to that terminal node will be printed; or he may request that the shortest paths to all nodes be printed.

After these results have been summarized, the user is permitted to run a new optimization from a new initial node. He may also enter a new set of values, either from a tape or through the keyboard.

Figure 6 is a listing of the printed output from the optimization program for the example problem. For the minimum path analysis, node 7 (a landing) was selected as the point of departure and node 1 (the mill) as the destination. The "optimum path" from node 7 to node 1 is via nodes 6, 4, 3, and 2 (see fig. 7). The total estimated "cost" of following this path is 19.

Table 2--*Input explanation for the shortest path program*

Visual prompt on display or printer	Keyboard response	Explanation
	SCRATCH A	Clear calculator memory.
	LOAD 6	Load program from tape.
	RUN	Begin program execution.
LOAD LINK MATRIX OFF TAPE?	YES	The link matrix was previously stored on tape; prepare to retrieve it.
FILE # OF LINK MATRIX STORAGE?	0	Identify tape file number.
LOAD VALUES OFF TAPE?	NO	The link values have not previously been stored.
VALUE FOR LINK #1?	3	Enter values corresponding to the links as numbered in figure 4.
VALUE FOR LINK #2?	6	
VALUE FOR LINK #3?	9	Although the link values used in this example are whole numbers, decimal numbers may also be entered.
VALUE FOR LINK #4?	3	
VALUE FOR LINK #5?	4	
VALUE FOR LINK #6?	5	
VALUE FOR LINK #7?	3	Note that the values used here correspond to those in figure 1.
VALUE FOR LINK #8?	2	
VALUE FOR LINK #9?	8	
VALUE FOR LINK #10?	7	
VALUE FOR LINK #11?	2	
VALUE FOR LINK #12?	1	
VALUE FOR LINK #13?	6	
VALUE FOR LINK #14?	5	
VALUE FOR LINK #15?	5	
VALUE FOR LINK #16?	4	
VALUE FOR LINK #17?	3	
VALUE FOR LINK #18?	3	
VALUE FOR LINK #19?	2	
VALUE FOR LINK #20?	4	
VALUE FOR LINK #21?	1	
VALUE FOR LINK #22?	2	
WANT TO CHANGE ANY LINK VALUES?	NO	This option is provided for correcting wrong entries; in this example, no corrections are necessary.
WANT TO ADD A LINK?	NO	
WANT TO ERASE A LINK?	NO	These options are provided for making corrections or revising the network; here, no corrections or revisions are necessary.
STORE LINK MATRIX?	NO	The link matrix has not been changed, and it is already stored on file 0.
STORE VALUES?	YES	Indicate that the link values are to be stored.
FILE # (NOTE: SIZE MUST BE >512)?	1	Store link values on file 1.
*******MINIMUM PATH ANALYSIS		
INITIAL NODE IN PATH?	7	Node 7 (a landing) is selected as the point of departure.
TERMINAL NODE (999=ALL NODES)?	1	Node 1 (the mill) is selected as the destination; if 999 had been entered, the minimum paths from node 7 to all nodes would have been printed.

. . . (the minimum path summary is printed here). . . .

Visual prompt on display or printer	Keyboard response	Explanation
ANOTHER TERMINAL NODE?	NO	These options are provided for running additional analyses.
OTHER PATHS FROM ANOTHER NODE?	NO	
TRY DIFFERENT SET OF VALUES?	NO	

. . . (program terminates) . . . .

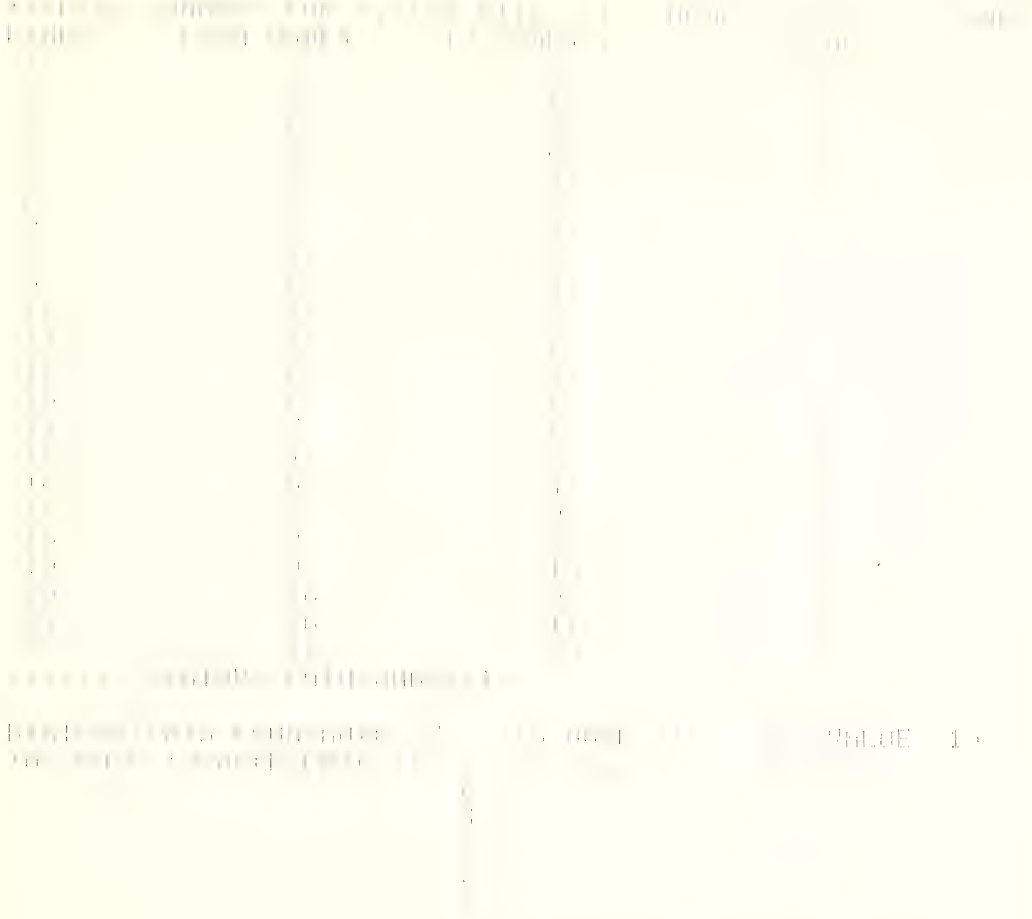


Figure 6.--Printed output from the shortest path program (loaded from tape file 6) for the example problem.

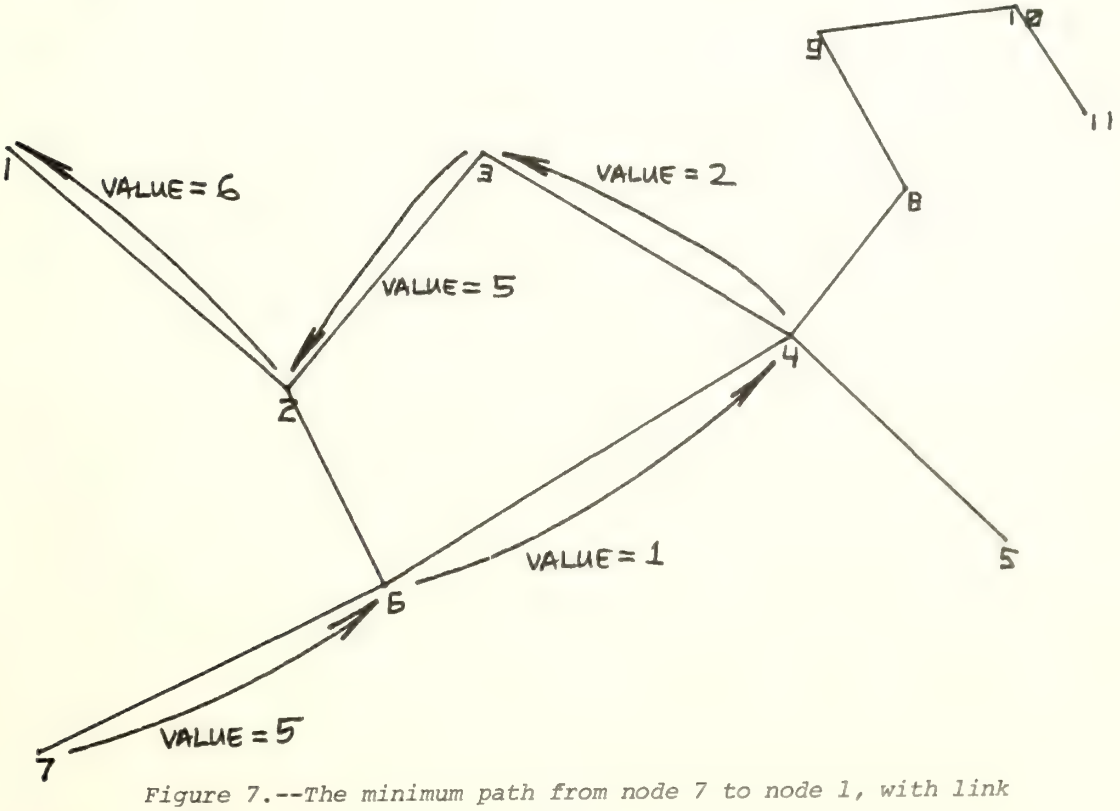


Figure 7.--The minimum path from node 7 to node 1, with link values for the selected links.

Concluding Remarks

The network analysis package described in this paper is intended for use with the small- to intermediate-size networks commonly encountered in planning transportation in forests. It is not suited to the analysis of large networks. Probably the most attractive feature of this package is the network generation capability which permits rapid, dependable entry of the network via a digitizer/plotter system. Also attractive is the interactive, problem-solving feature of the programs, made possible by the stand-alone capability of the desk-top programable calculator system.

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Appendix

Listing of the Network Generator Initialization Program

```
10 [illegible]
20 [illegible]
30 [illegible]
40 PRINT TAB5"[illegible]
50 PRINT TAB5"[illegible]
60 PRINT TAB5"[illegible]
70 PRINT TAB5"[illegible]
80 PRINT TAB5"AFTER THE [illegible]
90 PRINT TAB5"A PROGRAM [illegible]
100 PRINT TAB5"THE FIRST [illegible]
110 PRINT TAB5"SIZE [illegible]
120 [illegible]
130 DISP "DOCUMENT HORIZ. [illegible]
140 INPUT G1
150 DISP "DOCUMENT VERT. [illegible]
160 INPUT G2
170 [illegible]
180 PRINT TAB5"WAIT FOR THE -SELECT FUNCTION KEY(F4)-- MESSAGE,THEN PROCEED."
190 PRINT TAB[illegible]
200 [illegible]
210 FOR I=1 TO 60
220 FOR J=1 TO 10
230 [illegible]
240 NEXT J
250 NEXT I
260 DISP "SELECT FUNCTION [illegible]
270 STOP
280 END
```

Listing of the Network Generator Program on Special Function Key f_0

[illegible]

```
510 REM [illegible]
520 IF [illegible]
530 PRINT "TRANSFORMED [illegible]
540 GOTO [illegible]
550 [illegible]
560 [illegible]
570 IF [illegible]
580 PRINT [illegible]
590 [illegible]
600 GOTO [illegible]
610 [illegible]
620 [illegible]
630 [illegible]
640 [illegible]
650 CPLOT -1,-1
660 [illegible]
670 REM [illegible]
680 FOR [illegible]
690 IF [illegible]
700 IF [illegible]
710 REM [illegible]
720 [illegible]
730 GOTO 770
740 NEXT J
750 PRINT [illegible]
760 END
770 PLOT [illegible]
780 PLOT [illegible]
790 [illegible]
800 [illegible]
810 NEXT I
820 PRINT "NUMBER OF [illegible]
830 STOP
840 REM*****SUB*****[illegible]
850 FOR [illegible]
860 IF [illegible]
870 REM IF THERE ARE NOT [illegible]
880 NEXT J
890 RETURN
900 END
```

Listing of the Link Matrix Generator Program on Special Function Key f_1

```
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
330 NEXT J1
[illegible]
350 INPUT A$
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
```

Listing of the Shortest-path Program

```
[illegible]
```

```
[illegible]
[illegible] PRINT "LINE [illegible]
[illegible]
750 INPUT I1
[illegible]
860 N1=N1+1
[illegible]
900 INPUT A$
[illegible]
1020 STORE  DATA F9,L
```

```
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
1170 NEXT K
[illegible]
1190 FOR K=1 TO 60
[illegible]
[illegible]
[illegible]
[illegible]
1240 DISP "INITIAL NODE IN PATH";
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
1300 K1=K1+1
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
1410 IF K1=L1 THEN 1440
1420 REM CONTINUE LOOKING [illegible]
[illegible]
[illegible]
1450 FOR K=1 TO 20
[illegible]
1470 NEXT K
[illegible]
[illegible]
[illegible]
1510 GOTO 1280
[illegible]
[illegible]
1540 DISP "OTHER PATHS [illegible]
1550 INPUT A$
1560 IF A$="YES" THEN 1120
[illegible]
```

```
1580 INPUT A$
1590 IF A$="YES" THEN [illegible]
1600 GOTO [illegible]
1610 REM [illegible]
1620 IF [illegible] THEN [illegible]
1630 [illegible]
1640 FOR I=1 TO [illegible]
1650 IF [illegible] THEN [illegible]
1660 [illegible]
1670 [illegible] S1
1680 [illegible]
1690 GOTO [illegible]
1700 [illegible]
1710 [illegible]
1720 [illegible]
1730 FOR I=1 TO [illegible]
1740 IF [illegible] THEN [illegible]
1750 NEXT I
1760 [illegible] S1
1770 [illegible] J=T1
1780 RETURN
1790 REM***SUB***DETERMINATION OF NEXT [illegible]
1800 REM FIND MINIMUM VALUE OF SEQUENCE [illegible]
1810 [illegible]
1820 [illegible]
1830 [illegible]
1840 FOR K=1 TO 20
1850 IF [illegible] THEN 1890
1860 [illegible][K]
1870 [illegible][K]
1880 [illegible]
1890 REM PRINT TAB([illegible]
1900 NEXT K
1910 [illegible]
1920 [illegible]
1930 RETURN
1940 REM***SUB***DETERMINATION AND PRINTING OF MAXIMUM PATHS.
1950 DISP "TERMINAL NODE (999=ALL NODES)";
1960 INPUT K4
1970 FOR I=NL TO 1 STEP -1
1980 IF I#K4 AND K4#999 THEN 2150
1990 [illegible]
2000 [illegible]
2010 [illegible]
2020 [illegible]
2030 IF [illegible][K2]=0 THEN 2060
2040 [illegible][K2]
2050 GOTO 2010
```

```
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] RETURN
[illegible] END
```

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Fairbanks, Alaska
Juneau, Alaska
Bend, Oregon
Corvallis, Oregon
La Grande, Oregon
Portland, Oregon
Olympia, Washington
Seattle, Washington
Wenatchee, Washington

Mailing address: Pacific Northwest Forest and Range
Experiment Station
P.O. Box 3141
Portland, Oregon 97208

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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